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INPUT PARAMETER SPECIFICATION FOR THE LONGLEY-RICE AND JOHNSON-GIERHART TROPOSPHERIC RADIO PROPAGATION PROGRAMS, 0.02-40 GHz

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Richard L. Hocker

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The Longley-Rice and Johnson-Gierhart prediction programs of the Institute for Telecommunication Sciences are statistical/semi-empirical models of tropospheric radio propagation for low and high altitude scenarios, respectively, in the frequency range 0.02 - 40 GHz. These programs have been acquired by The MITRE Corporation and have been made compatible with the IBM-370 computer at MITRE, Bedford. This report describes these programs with particular emphasis on input parameter specification.

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PREDICTION PROGRAMS
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TERRAIN ROUGHNESS
TROPOSPHERIC
TROPOSPHERIC SCATTER

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SECTION 1

INTRODUCTION

The Longley-Rice[(1)-(3),(20)] and Johnson-Gierhart[(4)-(6)] prediction programs of the Institute for Telecommunication Sciences are statistical/semi-empirical models of tropospheric radio propagation for low and high altitude scenarios respectively in the frequency range 0.02 - 40 GHz. These programs are restricted to frequencies above 20 MHz because "sky" and "ground" wave propagation paths, which can be dominant propagation paths at frequencies less than 20 MHz, are not included in these programs. These programs are restricted to frequencies less than 40 GHz because the empirical data base does not include absorption and refractivity of the atmsophere or ground at wavelengths shorter than 1 cm.

Version 1.2.1 of the Longley-Rice program and the Air-to-Air (ATOA) version of the Johnson-Gierhart program have been acquired by MITRE Corporation for prediction of propagation path loss in radio scenarios. Version 1.2.1 of the Longley-Rice program is written in 1966 ANSI Fortran and therefore is compatible with most large computers. The Johnson-Gierhart ATOA program, which was originally written for a CDC CYBER-170/750 computer has been converted and made compatible with the IBM-370/3031 computer at MITRE Corporation.

The theory, computer programs, and user's guides for the Longley-Rice and Johnson-Gierhart prediction models are given in References [1] - [6], [20]. This paper discusses the input and output parameters of these prediction models, with particular emphasis on input parameter specification.

The outputs of these programs are statistical values of "basic transmission loss". In Section 2, basic transmission loss is defined and the particular quantities of basic transmission loss which are evaluated by these programs are discussed and compared with theoretical values. The motivation for using these programs are also given.

Input parameter specifications for the Longley-Rice and Johnson-Gierhart prediction models are described in Sections 3 and 4 respectively.

SECTION 2

BASIC TRANSMISSION LOSS

With reference to Figure 1, the predetection system margin $M(d,r_i)$ (in dB) of a radio, for a great circle path distance d and message quality r_i, is given by

$$M(d,r_i) = \overbrace{P_T - L_{N,T} - L_{M,T} - L_{C,T} + D_T - L_b(d) + D_R}^{S(d)} - N - R_r(r_i) \quad (2.1)$$

where

$S(d)$ = available signal power at the output terminals of the equivalent lossless receiving antenna (dBm)

P_T = transmitter carrier available outut power (dBm)

$L_{N,T}$ = insertion loss of transmitter transmission line (including reflection losses, if any) (dB)

$L_{M,T}$ = ohmic loss of matching network for the transmitting antenna (dB)

$L_{C,T}$ = ohmic loss of the transmitting antenna (dB)

D_T = directivity of the transmitting antenna (dBi)

$L_b(d)$ = basic transmission loss of propagation path (dB)

D_R = directivity of the receiving antenna (dBi)

N = system available noise power at the output terminals of the equivalent lossless receiving antenna (dBm)

$R_r(r_i)$ = required predetection signal-to-noise ratio (dB)

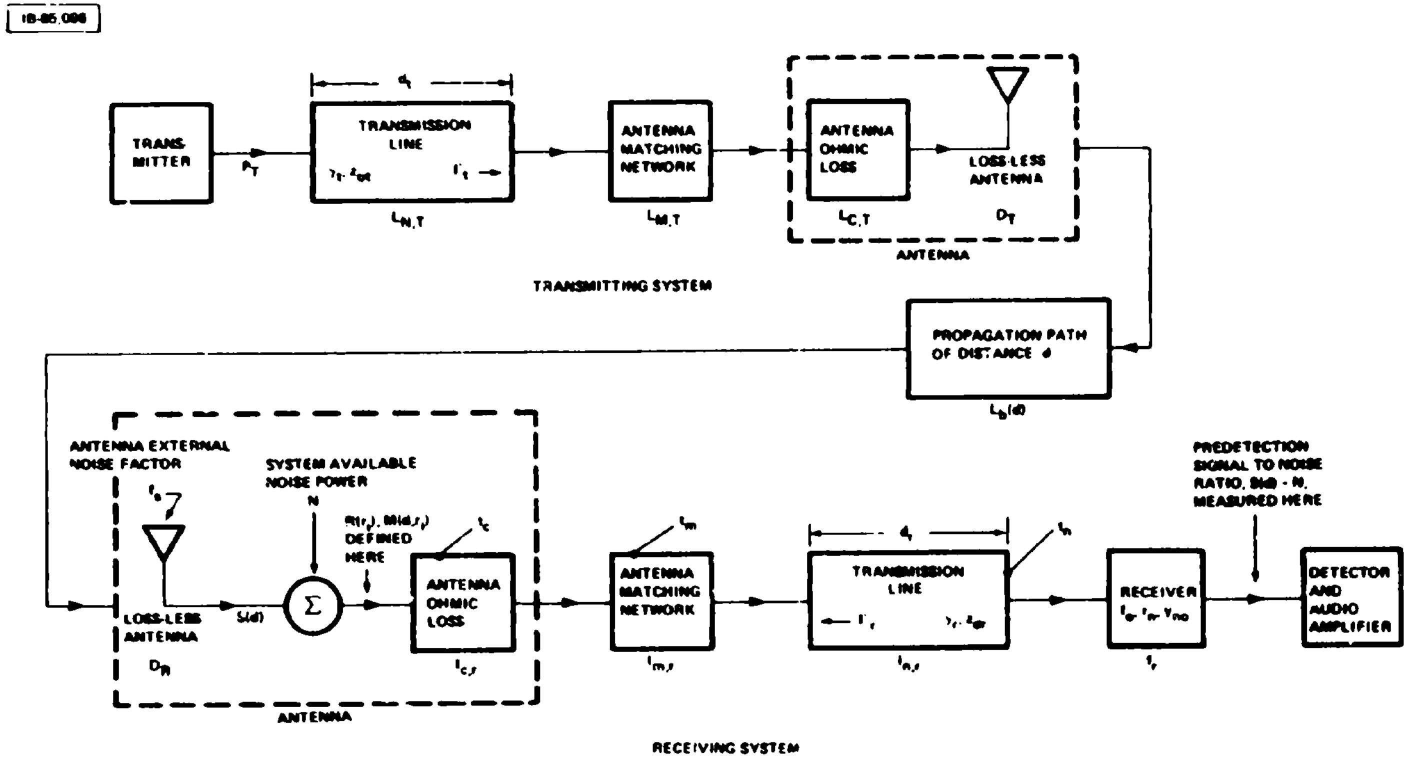

FIGURE 1: RADIO SYSTEM MARGIN PARAMETERS

The convention is followed that capitalized margin parameters are in units of dB whereas uncaptialized margin parameters refer to their numerical values.

The basic transmission loss $L_b(d)$ is the margin parameter random variable in Eq. (2.1) that is a function of the propagation range of great circle distance d between the transmitting and receiving antennas. More specifically, "the basic transmission loss (sometimes called path loss) of a radio circuit is the transmission loss expected between ideal, loss-free, isotropic, transmitting and receiving antennas at the same locations as the actual transmitting and receiving antennas"[7].

The basic transmission loss $L_b(d)$ (in dB) may be expressed as:

$$L_b(d) = L_{bo}(d) + U(d) + V(d) \tag{2.2}$$

where

$L_{bo}(d)$ = local path propagation loss for a path with no buildings or significant vegetation in the immediate vicinity of the antennas (hourly median value, in dB)

$U(d)$ = urban area propagation loss term resulting from buildings in the immediate vicinity of the antennas (hourly median value, in dB)

$V(d)$ = vegetative propagation loss term resulting from significant vegetation in the immediate vicinity of the antennas (hourly median value, in dB)

The propagation path loss given by Eq. (2.2) does not include rapid fading, about the hourly median value, of the received signal which results from multipath interference (vertical lobing) for a small change in range (of the order of a carrier wavelength) in a mobile system operating over irregular terrain. Instead of superimposing the distributions of hourly median and rapid fading propagation losses, the effects of multipath rapid fading can be included in the system margin model by increasing the value of the required predetection signal-to-noise ratio $R_r(r_i)$ necessary to obtain a specified channel quality r_i in the presence of rapid fading[8].

The local path propagation loss $L_{bo}(d)$ in Eq. (2.2) may be expressed as:

$$L_{bo}(d) = L_{bf}(d) + A(d) \tag{2.3}$$

where

$L_{bf}(d)$ = free-space propagation loss (dB)

$$= 10 \log_{10} \left(\frac{4\pi d}{\lambda}\right)^2 = 10 \log_{10} \left(\frac{4\pi df}{c}\right)^2$$

$$= 32.447 + 20 \log_{10} f_{MHz} + 20 \log_{10} d_{km}$$

d_{km} = great circle distance between transmitter and receiver antennas (km)

λ = RF carrier wavelength (in units of d)

f_{MHz} = RF carrier frequency (MHz)

c = free-space velocity of propagation = 0.29979 km/μs

$A(d)$ = excess propagation loss over that of free space for a path with no buildings or significant vegetation in the immediate vicinity of the antennas (hourly median value in dB). This term is usually modelled by semi-empirical methods.

The Longley-Rice and Johnson-Gierhart prediction programs are concerned with estimating the hourly median values of excess propagation loss A(d) defined by Eq. (2.3). The urban loss U(d) and vegetative loss V(d) terms in Eq. (2.2) are not predicted by these programs. The rapid fading, about the hourly median values, is also not predicted by the Longley-Rice program but is an available vertical lobing option in the Johnson-Gierhart program. Before discussing the excess loss A(d), a brief review is given here of the urban loss U(d) and vegetative loss V(d) terms in Eq. (2.2).

The urban area propagation loss term U(d) in Eq. (2.2) has been estimated to have a median value U(d,50%) given by[9].

$$U(d,50\%) = \begin{cases} 16.5 + 15 \log_{10} (f_{MHz}/100) - 0.12\, d_{km}, & \text{urban area} \\ 0, & \text{both antennas are in open areas} \end{cases} \qquad (2.4)$$

which agrees within 1 dB with empirical data at 100 - 300 MHz and distances 10 - 70 km. The median value U(d,50%) given by Eq. (2.4) is the difference in the median values of excess propagation loss reported by Okumura[10] for urban areas and by Longley-Rice[2] for open areas. Eq. (2.4) is based on data for which the receiver antenna was near ground level (at a height of 3m) and the transmitter antenna was at various elevated heights of 30 - 600 m. At a frequency of 88 MHz and a distance of 35 km, the median value of the additional transmission loss from urban area clutter is found from Eq. (2.4) to be 11.5 dB.

The vegetative propagation loss term V(d) in Eq. (2.2) is appreciably less at VHF frequencies than at higher frequencies because vegetation is appreciably more transparent at longer wavelengths and because obstacles, such as vegetation, diffract more energy into shadow zones at longer wavelengths[9]. Only vegetation in the immediate vicinity of the antennas should be considered in estimating V(d) in Eq. (2.2) because knife-edge diffraction by vegetation distant from the antennas is usually included in the semi-empirical methods used for estimating the excess propagation loss A(d). The loss term V(d) is the lessor of the absorptive path loss through the vegetation and the diffractive path loss over the vegetation.

When one of the antennas is placed near a grove of trees or in a jungle, vertically polarized VHF radio waves are attenuated appreciably more than horizontally polarized waves. For example, at 30 MHz and 100 MHz, the average loss from nearby trees was reported to be 2 - 3 dB and 5 - 10 dB respectively with vertical polarization and approximately 0 dB and 2 - 3 dB respectively for horizontally polarized signals[(9),(11)]. In dense jungles, vertically polarized waves can be attenuated about 15 dB more than horizontally polarized fields[(9),(12)]. At higher frequencies, the effects of polarization on vegetative loss are not as pronounced.

In experimental studies by La Grone[(13)] of propagation of horizontally polarized waves behind a grove of 3 m tall live-oak and blackberry trees on flat ground in Texas at frequencies 0.5 - 3 GHz and at distances greater than five times the tree height, measurements of path loss were in good agreement with theoretical predictions of diffraction over an ideal knife edge assuming distances and heights the same as those in the measurements. For such a case, the loss term V(d) may be interpreted as the difference in losses between knife-edge (tree) diffraction and smooth spherical earth diffraction with losses expressed in dB. Approximate numerical values, deduced from data for the above case, are V(d) = -4, -2, and +2 dB for receiver heights above local terrain of 2, 10, and 18 m respectively, a frequency of 82 MHz, transmitter to receiver distance d = 67 km, transmitter height of 424 m, and receiver to grove distance of 111 m.

Estimates of the excess propagation loss A(d) defined in Eq. (2.3) can be as formidable to calculate as the estimates for urban area and vegetative propagation losses because of the semi-empirical nature of the required models.

The excess propagation loss A(d) is generally a stochastic quantity because the scenarios of interest are generally not for deterministic propagation paths but are for specified classes of propagation paths. For example, the propagation paths may be specified as being over irregular terrain characterized by rolling plains, average ground permittivity, and random siting.

Radio waves generally may be propagated (a) through or along the surface of the earth (ground wave), (b) through the lower atmosphere of the earth beneath the ionosphere (tropospheric propagation) or (c) by reflection or scatter in the upper atmosphere (sky wave) from natural reflectors (ionosphere, aurora) or artificial reflectors (satellites). At frequencies greater than 20 MHz, ground wave propagation losses (except for very short paths within the radio horizon and along the earth's surface) and sky wave propagation losses (except for very long propagation paths beyond the radio horizon) are usually very much larger than tropospheric propagation losses. The Longley-Rice and Johnson-Gierhart programs consider only tropospheric propagation paths.

For tropospheric propagation over irregular terrain, the possible modes of propagation may be categorized as:

(1) multipath interference
(2) multipath - diffraction transition
(3) diffraction (smooth spherical earth and knife-edge)
(4) diffraction - tropospheric scatter transition
(5) tropospheric scatter

The regions for these propagation modes are shown in Figure 2.

Mode (1) is the dominant mode of propagation for line-of-sight paths which clear the radio horizon by greater than approximately 1/8 of a Fresnel number where the Fresnel number is the number of half-wavelengths of the path difference between the direct ray and the indirect ray which is specularly reflected from the ground[14]. Mode (2) occurs for line-of-sight propagation paths which are within 1/8 Fresnel number of the radio horizon. Mode (3) occurs for propagation paths which are beyond the radio horizon by more than 1/8 Fresnel number but less than that for which tropospheric scatter starts to become significant. Mode (4) is a transition mode between diffraction and troposcatter modes. Mode (5) occurs for propagation paths which are sufficiently beyond the radio horizon that tropospheric scatter losses are less than diffractive losses. Except for mode (1) lobing, the excess propagation loss A(d) generally increases with decreasing height h_2 as the dominant mode of propagation progresses from (1) to (5).

As an example of tropospheric modes (1) and (2), consider the various scenarios shown in Table 1. For smooth earth, all of the Table 1 scenarios correspond to radio links within or on the radio horizon. However, for random siting of the ground-based radio on irregular terrain, the radio line-of-sight to low altitude aircraft will often be obstructed. In the case of nonobstructed radio line-of-sight over smooth terrain, the principal mode of propagation is smooth spherical earth diffraction coupled with multipath interference between the direct and indirect signals reflected by the terrain to the receiver. In the case of an obstructed radio line-of-sight over irregular terrain, the principal mode of propagation is smooth spherical earth diffraction coupled with

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REGION	MODE
(1)	MULTIPATH INTERFERENCE
(2)	MULTIPATH – DIFFRACTION TRANSITION
(3)	DIFFRACTION (SMOOTH SPHERICAL EARTH AND KNIFE-EDGE)
(4)	DIFFRACTION – TROPOSPHERIC SCATTER TRANSITION
(5)	TROPOSPHERIC SCATTER

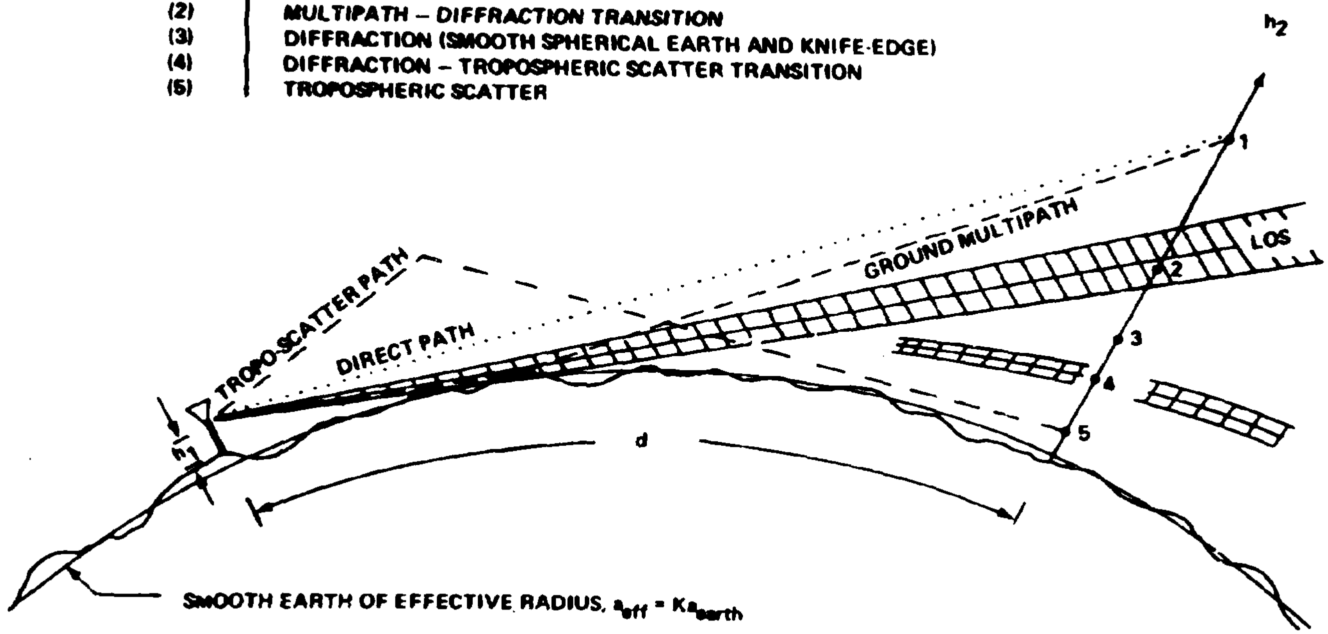
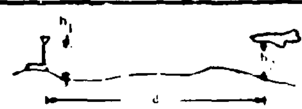


FIGURE 2: REGIONS FOR VARIOUS TROPOSPHERIC PROPAGATION MODES OVER IRREGULAR TERRAIN

No.	h_1 (m)	h_2 (m)	Desired Maximum Operational Range, d (km)	Grazing Angle (mrad)	No. of Fresnel Zones Clearance	Free Space Loss, L_{bf} (dB)	BASIC TRANSMISSION LOSS, L_b (dB)					
							Δh = 90 m		Δh = 225 m		Δh = 500 m	
							$\langle L_b \rangle$	σ_{L_b}	$\langle L_b \rangle$	σ_{L_b}	$\langle L_b \rangle$	σ_{L_b}
1	2.5	305	35	4.9	.014	97.4	112.7	11.0	118.0	11.9	126.8	12.2
2	2.5	75	28	1.1	.0029	95.4	124.9	10.9	126.5	11.8	134.2	12.2
3a	30	75	56	0.22	.032	101.4	131.5	11.1	132.3	11.7	135.0	12.0
3b	915	75	56	9.5	1.30	101.4	101.5	11.2	105.4	11.9	106.4	12.2
4a	2.5	150	28	1.9	.0097	95.7	118.2	11.0	119.2	11.8	127.4	12.2
4b	2.5	150	46	1.0	.00084	99.7	130.5	11.0	133.6	11.8	144.1	12.1
5	2.5	61	28	0.86	.0022	95.4	126.7	10.9	129.0	11.7	136.5	12.2
6a	2.5	150	46	1.0	.00084	99.7	130.5	11.0	133.6	11.8	144.1	12.1
6b	2.5	1070	112	3.1	.0017	107.4	136.1	11.2	154.6	12.1	154.6	12.1
7a1	2.5	5500	185	11.9	.050	111.8	118.9	1.4	128.2	1.6	150.2	1.8
7a2	2.5	5500	230	8.6	.040	113.7	128.8	2.6	145.0	2.7	158.1	2.8
7b1	2.5	6100	92	31.5	.111	105.7	107.9	0.0	106.7	0.0	135.4	0.0
7b2	2.5	6100	140	19.6	.071	109.3	114.3	0.1	112.4	0.3	140.8	0.8
7c1	2.5	4600	185	9.7	.041	111.8	120.7	1.7	144.2	2.0	154.5	1.9
7c2	2.5	4600	230	6.5	.033	113.7	134.0	3.0	151.7	3.2	160.3	3.2
8a1	9	9200	140	31.0	.40	109.3	110.4	0.0	110.0	0.0	109.7	0.0
8a2	9	9200	230	17.0	.24	113.7	117.7	1.4	116.9	1.5	118.8	1.6
8b1	915	9200	260	19.5	20.33	114.7	111.9	1.3	114.2	1.4	114.9	1.6
8b2	915	9200	300	15.8	13.64	116.0	115.7	2.0	115.7	2.0	115.7	2.0
9a	2.5	61	30	0.67	.0017	96.0	128.5	10.9	130.5	11.7	138.7	12.1
9b1	2.5	150	37	1.56	.0034	97.8	124.7	11.0	126.7	11.8	136.0	12.1
9b2	2.5	150	46	1.0	.00084	99.7	130.5	11.0	133.6	11.8	144.1	12.1



Average ground, conductivity, ... temperate climate, vertical polarization, and isotropic antennas in a non-vegetative open area are assumed.

Δh = interdecile terrain roughness

TABLE 1: BASIC TRANSMISSION LOSS FOR LOW AND HIGH ALTITUDE SCENARIOS, f = 50 MHz

knife-edge diffraction by the obstructing terrain. Multipath interference is the dominant mode of propagation in scenario numbers 3b, 7b1, and 8 which clear the radio horizon for a smooth earth by at least 1/8 Fresnel number. All of the other scenarios in Table 1, which clear the radio horizon by less than 0.01 Fresnel number, correspond to the multipath - diffraction transition mode.

In the multipath - diffraction transition mode, the propagation path loss is significantly larger than the free space loss. In the case of multipath interference, the interference is almost totally destructive because: 1) the Fresnel amplitude reflection coefficient is approximately -1 at low grazing angles of incidence; 2) the surface roughness reflection coefficient is approximately unity at sufficiently low grazing angles of incidence; 3) the path length difference between the direct and indirect signals is much less than a wavelength.

In the case of diffraction, the path loss increases exponentially with increasing distance of the transmitter or receiver into the shadow region of the obstructing terrain. For a given distance in the shadow region, the sharpness of the obstructing terrain appreciably alters the path loss in a diffraction mode. Therefore, for a diffraction mode of propagation, slope and height distribution of the obstructing terrain affect the path loss.

The Longley-Rice and Johnson-Gierhart statistical, semi-empirical programs are particularly useful in modeling propagation loss over irregular terrain in the transition modes (2) and (4) of Figure 2. The propagation loss for mode (2) is found from empirical data and from extrapolations between theoretical models for multipath interference and smooth spherical earth diffraction. The propagation loss for mode (4) is found from empirical data and from extrapolations between theoretical models for smooth spherical earth diffraction and tropospheric scatter.

The Longley-Rice prediction program is applicable to scenarios where both the transmitter and receiver antennas are at heights above local ground between 0.5 m and 3 km (which we shall designate as "low altitude" scenarios). The Johnson-Gierhart program is applicable to "high altitude" scenarios in which (1) the lower antenna is at a height above local ground between 0.5 m and approximately 3 km; (2) the higher antenna is less than 100 km but at a sufficient height above local ground that the elevation angle at the lower antenna of the terrain limited radio horizon is less than the elevation angle of the higher antenna; and (3) the terrain-limited radio horizon for the higher antenna is taken either as a common horizon with the lower antenna or as a smooth earth horizon with the same elevation as the lower antenna effective reflecting plane. These altitude restrictions and the use of these programs are based on the following considerations:

a. Whereas two-ray multipath interference models are adequate for path clearances greater than 1/8 Fresnel number and whereas smooth earth spherical diffraction models are adequate for transhorizon paths well beyond the radio horizon, an extrapolation between these models, even for a smooth earth, is presently required for modeling of propagation paths near the radio horizon(14). Reference [14] gives a deterministic computer program for such an extrapolation. However, for path loss averaged over random paths above irregular terrain near the radio horizon, a semi-empirical, stochastic extrapolation is required. The empirical weighting accounts for knife-edge diffraction effects over a rough earth. The Longley-Rice semi-empirical prediction program does such an extrapolation and allows for double horizon diffraction for both random and specific terrain profiles.

b. Probabilistic predictions of path loss are possible because the data base includes many samples for various locations, time of year, and experimental situations. Much of the data base for the Longley-Rice program is for double horizon diffraction paths and was obtained in the frequency range 20 - 100 MHz[15]. Much of the data base for the Johnson-Gierhart program is from 200 single horizon diffraction paths contained in the data of Longley, et al[16].

c. The Longley-Rice program assumes a uniform atmosphere (linear refractive gradient) and is therefore not applicable to propagation paths in standard exponential atmosphere at elevations above 3000 m. The Longley-Rice program is also restricted at each antenna to path elevation angles less than 12°. For path elevation angles greater than 12°, time variability of path loss caused by atmospheric refraction is appreciably less than that of the empirical data base (which is limited to refractive effects at elevation angles less than 12°).

d. The Johnson-Gierhart prediction program is restricted to single-horizon diffraction which allows for ray tracing in standard atmospheres from the horizon back to the antenna site. The Johnson-Gierhart program is therefore applicable to paths at high elevations and steep elevation angles but is not applicable at low elevations where double horizon diffraction may be significant.

In the Longley-Rice and Johnson-Gierhart programs, ionospheric propagation and auroral scatter effects are assumed to be negligible. This assumption is valid at frequencies above 100 MHz and is expected to be valid at frequencies 20 - 100 MHz for sufficiently short path lengths. In the Longley-Rice program a print-out warning is issued at frequencies less than 40 MHz to remind the user that sky wave effects may be important at sufficiently long path lengths. The Johnson-Gierhart program can be extended to frequencies as low as 20 MHz provided that sky wave effects are negligible.

Both of these prediction programs restrict antenna sites to locations for which the ratio of the distance to the terrain-limited radio horizon to that for a smooth spherical earth is greater than 0.1 and less than 3.0. This restriction applies to both antenna sites in the Longley-Rice program and only to the lower antenna in the ATOA program. For example, these programs would not be applicable to a scenario in which the ground site is at the bottom of a steeply rising hill because the weighted extrapolation of models in these programs do not allow for severe knife-edge diffraction. The hourly median basic transmission loss computed by these programs does not include losses resulting from foliage or buildings.

In Figure 3, the cumulative distribution functions of path loss are plotted on normal probability paper for both high and low altitude scenarios. The path loss for the low altitude scenario of Table 1 (scenario no. 9a) was predicted utilizing the Longley-Rice model whereas the path loss for the high altitude scenario (scenario no. 7c2) was predicted utilizing the Johnson-Gierhart model. Whereas Longley-Rice program predictions of path loss for low altitude scenarios are approximately normally distributed when path loss is expressed in dB, Johnson-Gierhart program predictions of path loss for high elevation scenarios are two-piecewise normally distributed with a breakpoint at the median value as explained below. Location, time, and situation (model) uncertainties contribute to path loss variability. In the Longley-Rice program, location variability is usually the dominant path loss variability because diffraction by

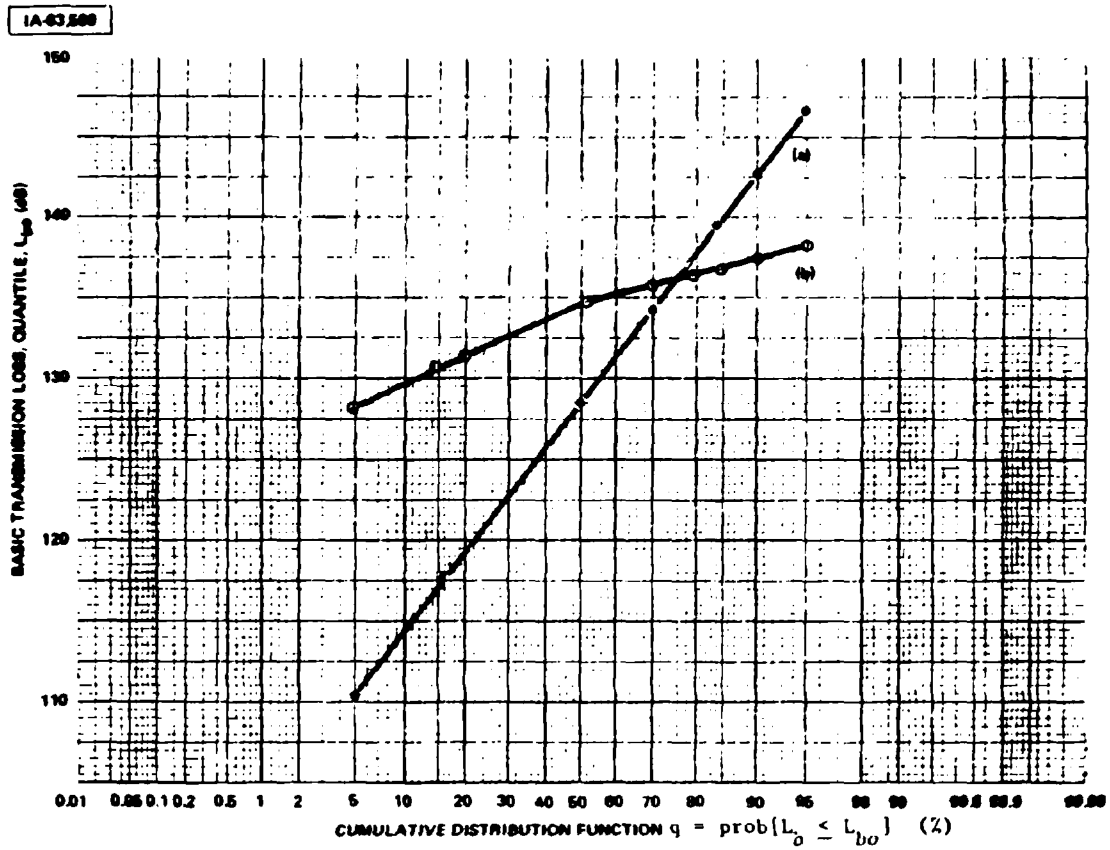


FIGURE 3: CUMULATIVE DISTRIBUTION FUNCTION OF BASIC TRANSMISSION LOSS, f = 50 MHz
a. LONGELY-RICE (h_1 = 2.5 m, h_2 = 61 m, d = 30 km)
b. JOHNSON-GIERHART (h_1 = 2.5 m, h_2 = 4600 m, d = 225 km)

terrain at both ends of the link is considered. In the Johnson-Gierhart program, time variability is usually the dominant path loss variability because diffraction by terrain at only the low altitude end of the link is considered. Location and time variabilities are one-piecewise and two-piecewise, respectively, normally distributed in both programs.

The Longley-Rice and Johnson-Gierhart programs predict the hourly median quantiles $L_{bo}(d,q)$ of the basic transmission $L_b(d)$ as a function of the path distance d and the cumulative distribution function (confidence level) $q = \text{prob}\,[L_b(d) \leq L_{bo}(d)]$. The single variate probability q, in which marginal probabilities of time, location, and situation (model uncertainity) are combined, is the only statistical service (designated single-message service) available in the Johnson-Gierhart program. In the Longley-Rice program other statistical services are also available (see section 3.0, Table 5.)

For the Johnson-Gierhart program, in which path loss $L_b(d)$ is two-piecewise normally distributed with a breakpoint at the median value $L_b(d, 50\%)$, the expected value $\langle L_b(d) \rangle$ and standard deviation $\sigma_{L_b(d)}$ are given by

$$\langle L_b \rangle = L_{bo}(50\%) + 0.312\,[L_{bo}(90\%) + L_{bo}(10\%) - 2L_{bo}(50\%)], \qquad \text{two-piecewise normal} \qquad (2.5)$$

$$\sigma_{L_b} = \frac{1}{1.28} \left\{ \frac{1}{2}\,[L_{bo}(90\%) - L_{bo}(50\%)]^2 + \frac{1}{2}\,[\,L_{bo}(50\%) - L_{bo}(10\%)]^2 - \frac{1}{2\pi}\,[L_{bo}(90\%) + L_{bo}(10\%) - 2L_{bo}(50\%)]^2 \right\}^{1/2}, \qquad \text{two-piecewise normal} \qquad (2.6)$$

In Eqs. (2.5) and (2.6), the parameter d has been suppressed in order to condense the notation.

For the Longley-Rice program, in which path loss $L_b(d)$ for the low-altitude scenarios is normally distributed, $\langle L_b(d) \rangle$ and $\sigma_{L_b}(d)$ are given by

$$\langle L_b(d) \rangle = L_{bo}(d,\ 50\%),\ \text{normal} \tag{2.7}$$

$$\begin{aligned} \sigma_{L_b}(d) &= \frac{1}{1.28}\,[L_{bo}(d,\ 90\%) - L_{bo}(d,\ 50\%)] \\ &= L_{bo}(d,\ 84.1\%) - L_{bo}(d,\ 50\%),\ \ \text{normal} \end{aligned} \tag{2.8}$$

Eqs. (2.5) and (2.6) reduce to Eqs. (2.7) and (2.8) respectively for $L_{bo}(90\%) = L_{bo}(10\%)$.

Both the Longley-Rice and Johnson-Gierhart programs utilize information based on the same statistical-empirical study of various terrain profiles and propagation measurements conducted primarily in the United States. In that study, each terrain profile was characterized by its interdecile height Δh and distance to the radio horizon. The interdecile height is the difference in heights corresponding to the 90% and 10% values of the cumulative distribution function for the height deviation from the mean surface level. When random siting is specified for an antenna above a surface of specified interdecile height, the programs assign a median distance to the radio horizon on the basis of information derived from the statistical-empirical study.

The statistical parameters $L_b(d)$ and $\sigma_{L_b}(d)$ are tabulated in Table 1. The basic transmission loss is tabulated for interdecile terrain heights Δh = 90 m, 225 m, and 500 m corresponding respectively to hills (U. S. average terrain), mountains (slightly shorter than those in the Fulda gap of Germany), and rugged mountains (slightly taller than those in Korea). The results of Table 1 are for average ground permittivity, random siting of the antennas, atmospheric refractivity at the earth's surface equivalent to an effective earth radius equal to 4/3 earth's geometric radius, temporate climate, vertical polarization, and isotropic antennas in a non-vegetative open area.

The expected value of the basic transmission loss exceeds the free-space loss, for Δh = 90 m, 225, and 500 m, by 1.1 dB, 0.7 dB, 0.4 dB respectively for the high-altitude scenario no. 8a1 and by 32.5 dB, 34.5 dB, and 42.7 dB respectively for the low-altitude scenario no. 9a. The standard deviation $\sigma_{L_b(d)}$ is 0 - 3 dB for the high altitude scenarios of Table 1 and 10.9 - 12.2 dB for the low-altitude scenarios.

Longley-Rice predictions of basic transmission loss for worldwide environmental conditions are tabulated in Table 2 for scenario no. 9a of Table 1. Variations in terrain roughness and surface permittivity have an appreciable effect on the expected value of transmission loss. Very careful siting of the ground antenna can reduce transmission loss by approximately 6 dB over that for random siting. Variations in climate and atmospheric refractivity have relatively little effect on transmission loss for this scenario. In non-vegetated areas, vertically polarized waves have less path loss than for horizontal polarization. However, in vegetated areas, the reverse may be true (see earlier discussion of vegetative loss term).

It will be noted that transmission loss decreases with increasing terrain roughness for terrain roughness less than or comparable to the higher antenna height above the ground but increases with increasing terrain roughness for terrain appreciably larger than the higher antenna height. The reason is that obstructions with small interdecile heights do not appreciably reduce

Table 2

Basic Transmission Loss for Worldwide Environmental Conditions

Scenario Parameters: $h_1 = 2.5$ m, $h_2 = 61$ m, d = 30 km, f = 50 MHz, non-vegetated open area

* Baseline Environmental Parameters: $\Delta h = 90$ m, average ground permittivity, random siting, K = 4/3 earth radius, temporate climate, vertical polarization.

Environmental Parameter			Basic Transmission Loss L_b (dB) $\langle L_b \rangle$	σ_{L_b}
Terrain Roughness, Δh (m)				
0	(Perfectly Smooth)		132.6	7.1
5	(Water or Very Smooth Plains)		131.1	7.5
30	(Slightly Rolling Plains)		129.2	9.3
60	(Rolling Plains)		128.6	10.3
*90	(United States Average)		128.5	10.9
225	(Mountains)		130.5	11.5
500	(Rugged Mountains)		138.7	12.1
700	(Extremely Rugged Mountains)		145.5	12.5
Surface Permittivity				
ε	σ(S/m)			
4	.001	(Poor Ground)	130.9	10.9
* 15	.005	(Average Ground)	128.5	10.9
25	.02	(Good Ground)	127.3	10.9
81	5.	(Sea Water)	113.4	10.9
81	.01	(Fresh Water)	124.4	10.9
Siting Criteria For Ground Facility				
* Random Siting			128.5	10.9
Careful Siting			125.1	10.9
Very Careful Siting			122.6	10.9
Climate				-
Equatorial			128.8	10.9
Continental Subtropical			128.5	10.9
Maritime Subtropical			128.5	10.9
Desert			129.0	10.9
* Continental Temporate			128.5	10.9
Maritime Temporate Overland			128.6	10.8
Maritime Temporate Oversea			128.5	10.9
Atmospheric Refractivity				
K (Earth Radius)	N_s (N-units)			
1.23	250		129.0	10.9
* 1.33	301		128.5	10.9
1.49	350		127.9	10.9
1.77	400		127.2	10.9
Polarization				
* Vertical			128.5	10.9
Horizontal			133.2	10.9

path clearance but instead enhance propagation by knife-edge diffraction. For obstructions with large interdecile heights, the exponential increase of the path loss with increasing distance into the shadow region of the obstructing terrain exceeds any reduction in path loss obtained by the knife edges of the obstructing terrain. When smooth spherical earth diffraction is the dominant mode of propagation, surface permittivity and particularly ground conductivity have appreciable effects on the distribution of energy above and below the earth's surface. For example, in Table 2, the transmission loss is approximately 17 dB less for propagation paths over sea water than for over very dry (poor) ground.

For non-vegetated open areas, the expected value and standard deviation of the excess propagation loss A(d) are relatively frequency insensitive, over the frequency range 30 - 88 MHz, when compared to the variation of free-space loss over this frequency range (see Table 3).

A comparison of theoretical models with Longley-Rice predicted values is given in Table 4 for scenario no. 9a of Table 1 and an interdecile terrain roughness $\Delta h \approx 0$. The theoretical models which are considered are free space, plane earth multipath, and spherical earth multipath. The semi-empirical model gives an expected value which exceeds the free-space loss by 35.4 - 37.5 dB over the frequency range 30 - 88 MHz. The plane-earth multipath model predicts a loss which is 1 to 6 dB larger than that predicted by the Longley-Rice model. The spherical earth multipath model predicts a loss which is appreciably less than that predicted by the Longley-Rice model but is more than the free-space loss. The close agreement, between the results for the multipath plane earth model and those of the Longley-Rice model, should be viewed as just a coincidence because the multipath plane earth model is only an

TABLE 3: FREQUENCY SCALING OF EXCESS PROPAGATION LOSS OVER FREE-SPACE LOSS

SCENARIO PARAMETERS: h_1 = 2.5 m, h_2 = 61 m, d = 30 km, average ground permittivity, random siting, K = 4/3 earth radius, temporate climate, vertical polarization, non-vegetated open area.

INTERDECILE TERRAIN ROUGHNESS, Δh (m)	EXCESS PROPAGATION LOSS, A(d) (dB)							
	$\langle A(d) \rangle$			$\lvert \langle A(d) \rangle - \langle A_{50MHz} \rangle \rvert$	$\sigma_{A(d)} = \sigma_{L_b}(d)$			$\lvert \sigma_{A(d)} - \sigma_{A_{50MHz}} \rvert$
	30 MHz	50 MHz	88 MHz		30 MHz	50 MHz	88 MHz	
60	33.9	32.6	31.2	1.4	9.6	10.3	11.0	0.7
225	35.1	34.5	34.4	0.6	11.4	11.7	12.0	0.3
500	41.5	42.7	45.7	3.0	11.9	12.1	12.2	0.2

TABLE 4: Comparison of Models for Basic Transmission Loss

(h_1 = 2.5 m, h_2 = 61 m, d = 30 km, Average ground, random siting, terrain roughness Δh = 0 m, effective earth radius K = 4/3, temporate climate, vertical polarization)

Model	Basic Transmission Loss, L_b (dB)		
	30 MHz	50 MHz	88 MHz
Longley-Rice, 50% confidence level	129.0	132.6	136.3
Free space	91.5	96.0	100.9
Plane earth multipath, R = -1	135.4	135.4	135.4
Spherical earth multipath, R = $R_o D$	101.3	105.8	110.7

Free Space

$$L_{bf}(d) = 20 \log_{10} (4\pi d/\lambda)$$

$$= 32.447 + 20 \log_{10} f + 20 \log_{10} d \text{ (dB)}$$

Multipath Mode over a Plane Earth at Low Grazing Angles and with an Amplitude Reflection Coefficient R = -1

$$L_b(d) = -20 \log_{10} (h_1 h_2/d^2) \quad \text{(dB)}$$

(From W. C. Jakes, Jr., "Microwave Mobile Communications", John Wiley, NY, 1974, Eq. 2.1-8)

Multipath Mode over a Smooth Spherical Earth

$$L_b(d) = L_{bf}(d) - 20 \log_{10} |1 + R\, e^{j\Delta}| \quad \text{(dB)}$$

where

$L_{bf}(d)$ = free-space loss

R = $R_o D$ = amplitude reflection coefficient

R_o = Fresnel amplitude reflection coefficient(Eq 11-1)

D = Divergence coefficient (Monogram F)

Δ = Phase difference between direct and indirect ray (Monogram D)

(From P. Beckmann and A. Spizzichino, "The Scattering of Electromagnetic Waves from Rough Surfaces", Pergammon Press, Oxford, 1963, Chapter 11.)

idealized limit of the more physical spherical earth multipath model which in turn is inappropriate for radio propagation paths that clear the radio horizon by less than 1/8 Fresnel number. The incremental path loss (expressed as a numeric rather than in units of dB) increases with incremental range to the second, fourth, and greater than fifth powers for the free-space, plane-earth multipath, and Table 2 Longley-Rice models respectively.

A comparison, of the Longley-Rice semi-empirical model with theoretical models and with empirical data in a multipath interference mode of propagation, has been reported[(17)-(19)]. It was found that both the Longley-Rice semi-empirical model and a statistical model, in which the surface height is assumed to be exponentially distributed, give good agreement with experimental data for coherent scatter in the forward-scatterd direction for both terrain and sea surfaces. The theoretical model for the particular mode of propagation has the advantages of providing a theoretical basis for the results and better agreement with data for very smooth surfaces and possible very rough surfaces. However, for the multipath diffraction transition mode of propagation near the radio horizon over an irregular terrain, the Longley-Rice semi-empirical model appears to be the best available model because there presently is no adequate theoretical model.

SECTION 3

INPUT PARAMETER SPECIFICATION FOR LONGLEY-RICE, VERSION 1.2.1, PREDICTION PROGRAM

The Longley-Rice, version 1.2.1, propagation program predicts long-term (hourly) median radio transmission loss over irregular terrain. The output of the program is basic transmission loss. The program combines well-established propagation theory with empirical data to predict propagation lcsses. The prediction program is applicable for radio frequencies above 20 MHz. For frequencies below 40 MHz, a warning is automatically printed out, regardless of path distance, to remind the user that the sky wave may be significant for sufficiently long paths. The program may be used either with terrain profiles that are representative of median terrain characteristics for a given area (the area prediction mode) or with detailed terrain profiles for actual paths (the point-to-point mode).

The empirical data base is for wide ranges of frequency, antenna height and distance, and for all types of terrain from very smooth plains to extremely rugged mountains. The data base includes more than 500 long-term recordings at fixed locations throughout the world in the frequency range 40 MHz to 10 GHz, and several thousand mobile recordings in the United States at frequencies from 20 MHz to 1 GHz. Much of the empirical data base is in the VHF frequency band 30-100 MHz.

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The program is intended for use within the following ranges:

Parameter	Range
frequency	20 - 40,000 MHz
antenna heights	0.5 - 3,000 m
distance	1 - 2,000 km
surface refractivity	250 - 400 N-units
elevation angle, of the irregular terrain radio horizon ray above the horizontal, at <u>each</u> antenna	0 - 12 degrees
relative distance, from <u>each</u> antenna to its terrain horizon, normalized to the corresponding smooth-earth distance	0.1 - 3.0

The elevation angles and radio horizon distances are not program input parameters but are computed internally by the program.

Version 1.2.1 is written in ANSI Fortran language and is therefore compatible with any large scale computer.

The input parameter specifications for version 1.2.1 are given in Table 5 which includes numerical ranges of parameters and the numerical values for which a warning is automatically printed out. An asterisk denotes the numerical value that will be assumed for a parameter if the user does not specify a particular value.

Version 1.2.1 offers two program modes whose selection depends upon how the user wishes to specify the terrain surface profile: the area prediction mode, designated "QKAREA"; and the point-to-point mode, designated "QKPFL". The area prediction mode is characterized by specifying the interdecile height Δh, the antenna siting criteria,

NO.	PARAMETER	RANGE	WARNING CONDITION	VALUE
	SYSTEM PARAMETERS			
1	Frequency, f (FMHZ)	20 - 40000 MHz, *100 MHz	< 40 MHz	______ MHz
2	Antenna Height Above Ground at Terminal 1, h_{g1} (HG1)	0.5 - 3000 m, *1 m Subject to the condition that the elevation angle θ_{e1}, of the horizon ray above the horizontal at the antenna, is less than 12° for the specified ground profile.	< 1 m or > 1000 m or $\theta_{e1} > 12°$	______ m
3	Antenna Height Above Ground at Terminal 2, h_{g2} (HG2)	0.5 - 3000 m, *1 m Subject to the condition that the elevation angle θ_{e2}, of the horizon ray above the horizontal at the antenna, is less than 12° for the specified ground profile.	< 1 m or > 1000 m or $\theta_{e2} > 12°$	______ m
4	Antenna Polarization, P (POL) (Identical Polarization Assumed for Both Antennas)	0 - Horizontal, *1 - Vertical	None	______
5	Great Circle Distance Between Terminals d (D0, D1, DE1, D2, DE2) The values of d, for which the basic transmission loss $L_b(d)$ is printed-out, are specified as follows: Area Prediction Profile Mode Specify a) or b) or c) a) $d = d_o$ - only the single distance d_o b) $d = d_o, d_1, d_{e1}$ - Distances from d_o to d_1, in steps of d_{e1} c) $d = d_o, d_1, d_{e1}, d_2, d_{e2}$ - Distances from d_o to d_1 in steps of d_{e1} and distances d_1 to d_2 in steps of d_{e2}	1 - 2000 km, *$d = d_o, d_1, d_{e1}, d_{e2}$ = 10, 150, 10, 500, 50 Subject to the condition $0.1 \leq \frac{d_{L1,2}}{d_{Ls1,2}} \leq 1$ where d_{L1} and d_{Ls1} are the distances from antenna 1 to its horizon for ground profile and smooth - spherical earth conditions respectively	< 1 km or > 2000 km or $\frac{d_{L1,2}}{d_{Ls1,2}} < 0.1$ or $\frac{d_{L1,2}}{d_{Ls1,2}} > 1$	______ km ___ ___ ___ _ _ _ _ _ km
	Point-to-Point Profile Mode $d = d_o$ - Only the single distance d_o	1 - 2000 km, *$d = n\ell$, subject to above condition		______ ______ km
	ENVIRONMENTAL PARAMETERS			
6	Climate, C (CLIM)	1 - Equatorial 2 - Continental Subtropical 3 - Maritime Subtropical 4 - Desert *5 - Continental Temperate 6 - Maritime Temperate Overland 7 - Maritime Temperate Oversea	Values other than integers 1 through 7	______

TABLE 5: INPUT PARAMETER SPECIFICATION, LONGLEY-RICE PREDICTION PROGRAM, VERSION 1.2.1

NO.	PARAMETER	RANGE	WARNING CONDITION	VALUE
7	ATMOSPHERIC REFRACTIVITY			
	OPTION 1 - SPECIFY a) and b)			
	a) Average elevation of ground surface above mean sea level, Z_s (ZSYS)	-400 m to +10000 m, *0 m	None	______ m
	b) Minimum monthly mean of atmospheric refractivity at sea level, N_0 (EN0)	250 - 400 N-Units, $^*N_s$	< 250 N-Units or > 400 N-Units	______ N-units
	OPTION 2 - SPECIFY c)			
	c) Atmospheric refractivity at average elevation of ground surface, N_s (ENS)	250 - 400 N-Units *301 N-units (corresponds to k = 1 1/3, effective earth radius)	Negative values	______ N-units
8	SURFACE PERMITTIVITY SPECIFY a) and b)			
	a) Surface dielectric constant, ε (EPS)	1 - Infinity, *15 (see estimates below)	< 1	______
	b) Surface conductivity, σ (SGM)	0 - Infinity S/m, *0.005 S/m (see estimates below)	< 0	______ S/m
9	SURFACE PROFILE MODE	Mode options are specified by PROGRAM NAME, Parameter No. 15.		
	OPTION 1 - AREA PREDICTION MODE			
	SPECIFY a) b) and c)			
	a) Terrain irregularity, Δh (DELTA H)	0 - 10000 m (see estimates below)	None	______ S/m

TYPE OF GROUND	σ (S/m)	ε
Poor Ground	0.001	4
Average Ground	0.005	15
Good Ground	0.02	25
Fresh Water	0.01	81
Sea Water	5.0	81

TYPE OF TERRAIN	Δh (m)
Water or very smooth plains	0 - 5
Smooth plains	5 - 20
Slightly rolling plains	20 - 40
Rolling plains	40 - 80
Hills	80 - 150
Mountains	150 - 300
Rugged mountains	300 - 700
Extremely rugged mountains	> 700
United States average	90

TABLE 5: INPUT PARAMETER SPECIFICATION, LONGELY-RICE PREDICTION PROGRAM, VERSION 1.2.1 (cont.)

NO.	PARAMETER	RANGE	WARNING CONDITION	VALUE
9 Cont.	b) Siting criteria for terminal 1, S_1 (KST1)	*0 - Random. Antenna is low and randomly located with respect to hills and other obstructions 1 - Careful. Antenna is located on or near hilltop 2 - Very careful. Antenna is located on highest hilltop	Values other than integers 0, 1, 2	________
	c) Siting criteria for terminal 2, S_2 (KST2)	*0 - Random, 1 - careful, 2 - very careful	Values other than integers 0, 1, 2	________
	<u>OPTION 2</u> - Point-to-Point Mode Specify d), e), <u>and</u> (optional f). d) Elevation matrix, $[p]$ (PFL) $[p] = p_o, p_1, \cdots p_k \cdots p_n$ where p_o corresponds to the elevation of terminal 1, p_k $(0 \leq k \leq n)$ corresponds to the elevation at the k^{th} stepping interval, and p_n corresponds to the elevation at terminal 2 (n^{th} stepping interval).	Positive and negative values. *No default value. Profile is specified as a sequence of n + 1 elevations in arbitrary units at equal stepping intervals $\ell = d_o/n$ along the great cirle from the point under terminal 1 to that under terminal 2 where d_o is specified by parameter No. 5. Subject to the conditions $\theta_{e1,2} < 12°$ $0.1 \leq \frac{d_{L1,2}}{d_{Ls1,2}} \leq 3$	Less than two points specified or warning conditions of parameter nos. 2, 3 and 5.	— — -- - - - —
	e) Elevation scale factor, z_{sc} (ZSC) (Converts arbitrary units of elevation matrix to meters)	0 - Infinity m/unit *1 m/unit	None	________ m/unit
	f) Stepping interval, ℓ (XI) (Ignore if d_o is specified)	$0 < \ell < 1000$ km, $*d_o/n$.	$d_o \neq n\ell$	________ km
	<u>STATISTICAL PARAMETERS</u> The measured basic transmission loss, for a given set of system and environmental parameters, varies randomly with time, location, and situation. When expressed in dB, the measured loss is approximately normally distributed with respect to these variables. In the prediction program, location and situation variabilities of the loss are assumed to be normally distributed whereas the time variability of the loss is assumed to be piece-wise normally distributed. The statistical parameters determine the probability Q (Confidence level, parameter No. 12) that the predicted value of basic transmission loss L_b (d) is not exceeded with a specified reliability q (Parameter No. 11) for a specified service mode of variability V (Parameter No. 10).			
10	Service mode of variability, V (MDVAR) <u>Area Prediction Profile Mode</u> V = 0, Single-message service. This mode specifies the probability Q that the predicted value of L_b(d) is not exceeded on a single communication attempt. Time, location, and situation variabilities are combined together to give the confidence level Q. V = 1, Individual service. This mode specifies the probability Q that the predicted value of L_b(d) is not exceeded for at least a specified fraction q_T of the time (time reliability). Location and situation variabilities are combined to give the confidence level Q.	Specify value only for area prediction profile mode 0, 1, 2, or *3	Defaults to V = 3 if value other than 0, 1, 2, 3 is specified	________

TABLE 5: INPUT PARAMETER SPECIFICATION, LONGLEY-RICE PREDICTION PROGRAM, VERSION 1.2.1 (cont.)

NO.	PARAMETER	RANGE	WARNING CONDITION	VALUE
10 Cont.	V = 2, Mobile service. This mode specifies the probability Q that the predicted value of $L_b(d)$ is not exceeded for at least a specified fraction q_R of communication attempts (service reliability). Situation variability gives the confidence level Q. Time and location variabilities are combined to give the service reliability q_R. V = 3, Broadcast service. This mode specifies the probability Q that the predicted value of $L_b(d)$ is not exceeded for at least a specified fraction q_T of the time (time reliability) at each of at least a specified fraction q_L of locations (location reliability). Situation variability gives the confidence level Q. __Point-to-Point Profile Mode__ No option. Service mode is predetermined. This mode specifies the probability Q that the predicted value of $L_b(d)$ is not exceeded for at least a specified fraction q_T of the time (time reliability). Situation variability gives the confidence level Q. Location variability is not applicable to this mode.		None	
11	Reliability, {q} (QT, QR, QL) __Area Prediction Profile Mode__ $\{q\} = (q_T \text{ or } q_R), q_L$ where {q} is a sequence of two, or one values as specified below: V | q_T or q_R | q_L 0 | Not required | Not required 1 | q_T | Not required 2 | q_R | Not required 3 | q_T | q_L	0.1 - 99.9%, *50% for required values of q_T, q_R, q_L. A specified value of q_T, q_R, or q_L is ignored if not required.	< 0.1% or >99.9%	______ % ______ % ___ ___ %
	__Point-to-Point Profile Mode__ $\{q\} = q_{T1}, q_{T2}, \cdots q_{Tn}; 1 \leq n \leq 7$ where up to seven values may be specified for each printout.	0.1 - 99.9%, $*\{q\} = (q_{T1}, q_{T2}, q_{T3}) = (50\%, 90\%, 10\%)$	< 0.1% or >99.9%	— — — ... — %
12	Confidence level, {Q} (QC) $\{Q\} = Q_1, Q_2, \ldots Q_m; 1 \leq m \leq 7$ where up to seven values may be specified for each printout.	0.1 - 99.9%, $*\{Q\} = (Q_1, Q_2, Q_3) = (50\%, 90\%, 10\%)$	< 0.1% or >99.9%	— — — ... — %
	__TITLES__			
13	Program print-out title For area prediction mode For point-to-point mode	Up to 80 characters including spaces. *Area predictions from the Longley-Rice Model, Version 1.2.1 *Link predictions from the Longley-Rice Model, Version 1.2.1	None	
14	Path print-out title Specify only for Point-to-Point Mode	Up to 80 characters including spaces. *None	None	
15	Program Name URAREA (For Area Prediction Mode) URPPL (For Point-to-Point Mode)	URAREA, URPPL	[illegible] URAREA or URPPL	

*Asterisk denotes [illegible]

TABLE 5: INPUT PARAMETER SPECIFICATION, LONGLEY-RICE PREDICTION PROGRAM, VERSION 1.2.1 (cont.)

and the great circle distances for which the basic transmission loss $L_b(d)$ is printed out. The point-to-point mode is characterized by specifying the elevation matrix of the terrain profile. In the area prediction mode, the interdecile terrain height and antenna siting criteria determine the expected values of the antenna effective heights, the elevation angles, and the terrain horizon distances by means of the stored empirical data base. The point-to-point mode computes the elevation angles and distance to the radio horizon for each antenna and the antenna effective height by considering whether or not the antenna is near or on a hill. Except for these differences, the QKAREA and QKPFL programs are identical.

The input card set-ups for programs QKAREA and QKPFL are given in Tables A-1 and A-2 of Appendix A, respectively. The parameter fields for programs QKAREA, QKPFL and program control cards are given in Tables A-3, A-4 and A-5 of Appendix A, respectively.

A card deck consists of job control cards, input parameter card types, and program control card types.

There are four different job control cards. They preceed the rest of the deck and all are required in the sequence shown in the card set-up tables.

Input parameter card types 1 - 7 follow the job control cards. For QKAREA, there are as many as six card types for each "execute" operation. For QKPFL, there are as many as seven card types for each "execute" operation. Any parameters not specified (left blank) default to values noted in the input parameter specification table. Any card type can be omitted. If a card type is omitted, the program defaults to the values given in the input parameter specification table. If a card type is used, all cards in that card type must be specified in the sequence shown in the card set-up tables. Card types 1 - 7 can be inserted in any order.

There are three program control card types: 0 (stop), 8 (execute) and 9 (reset). The functions of these cards are:

stop - causes the program to execute, produce a printout and then terminates the job.

execute - causes the program to execute and produce a printout for a given set of input parameter card types.

reset - causes all parameters to be reset to their default values until additional input parameter card types are inserted.

The program control cards are placed after the four job control cards at approximate places within the card deck where their functions are required. Card type 0 is required for final execution and should be the last card in the deck. Card type 8 is placed in the card deck before each set of input parameter cards types. Card type 9 is used only if there is more than one set of input parameter card types required for additional runs and is placed after the execute card but before each additional set of input parameter cards.

Sample outputs for the Longley-Rice QKAREA and QKPFL programs are given in Tables 6 and 7 respectively.

TABLE 6: Sample Output, QKAREA

```
PROGRAM QKAREA

          FREQUENCY           50. MHZ
    ANTENNA HEIGHTS       2.5     75.0 M
  EFFECTIVE HEIGHTS       2.5     75.0 M   (SITING=0,0)
   TERRAIN, DELTA H          700. M

POL=1, EPS=15., SGM= 0.005 S/M
CLIM=5, NO=301., NS=301., K= 1.333

SINGLE-MESSAGE SERVICE

ESTIMATED QUANTILES OF BASIC TRANSMISSION LOSS(DB)
```

DIST KM	FREE SPACE	WITH CONFIDENCE 5.0	15.9	50.0	70.0	84.1	90.0	95.0
5.0	80.4	86.4	94.8	107.2	113.6	119.6	123.2	127.9
10.0	86.4	96.6	105.0	117.3	123.8	129.7	133.3	138.1
15.0	90.0	104.3	112.6	125.0	131.4	137.4	141.0	145.7
20.0	92.5	111.0	119.3	131.6	138.0	144.0	147.5	152.3
25.0	94.4	117.1	125.4	137.7	144.1	150.0	153.6	158.3
30.0	96.0	122.8	131.2	143.4	149.8	155.7	159.2	163.9
35.0	97.3	128.3	136.6	148.9	155.2	161.1	164.6	169.3
40.0	98.5	133.6	141.9	154.2	160.5	166.3	169.9	174.6
45.0	99.5	137.0	145.4	157.6	163.9	169.8	173.3	178.0
50.0	100.4	139.0	147.4	159.7	166.0	171.8	175.4	180.1
55.0	101.2	140.9	149.3	161.7	168.0	173.8	177.3	182.0
60.0	102.0	142.6	151.2	163.6	169.8	175.7	179.2	183.9
70.0	103.3	145.8	154.6	167.1	173.4	179.3	182.9	187.6
80.0	104.5	148.6	157.7	170.5	176.9	182.7	186.3	191.1
90.0	105.5	151.2	160.6	173.7	180.1	186.1	189.7	194.5
100.0	106.4	153.6	163.3	176.8	183.3	189.3	193.0	197.9
110.0	107.3	153.8	165.9	179.8	186.3	192.4	196.1	201.1
120.0	108.0	158.0	168.4	182.6	189.3	195.4	199.2	204.3

TABLE 7: Sample Output, QKPFL

```
QKPFL TEST 1, PATH 2200 (MEASURED MEDIAN LB=133.2 DB)

CRYSTAL PALACE TO MURSLEY, ENGLAND

          DISTANCE         77.8 KM
         FREQUENCY         41.5 MHZ
   ANTENNA HEIGHTS    143.9      8.5 M
 EFFECTIVE HEIGHTS    240.5     18.4 M
  TERRAIN, DELTA H          89. M

POL=0, EPS=15., SGM=  .005 S/M
CLIM=5, NS=314., K= 1.368
PROFILE- NP= 156, XI=  .499 KM

   A DOUBLE-HORIZON PATH
   DIFFRACTION IS THE DOMINANT MODE

ESTIMATED QUANTILES OF BASIC TRANSMISSION LOSS (DB)
   FREE SPACE VALUE-   102.6 DB

      RELIA-    WITH CONFIDENCE
      BILITY      50.0     90.0     10.0

        1.0      128.6    137.6    119.6
       10.0      132.2    140.8    123.5
       50.0      135.8    144.3    127.2
       90.0      138.0    146.5    129.4
       99.0      139.7    148.4    131.0
```

SECTION 4

INPUT PARAMETER SPECIFICATION FOR JOHNSON-GIERHART, AIR-TO-AIR (ATOA), PREDICTION PROGRAM

The Johnson-Gierhart ATOA prediction program is similar in many respects to the Longley-Rice prediction program. The ATOA program predicts radio transmission loss over irregular terrain. The output of the MITRE versions of the program is basic transmission loss. The program combines well-established propagation theory with empirical data to predict propagation losses which have been tested against a large number of propagation measurements. It is applicable to radio frequencies 100 MHz to 20 GHz but can also be used at frequencies as low as 20 MHz provided that the propagation paths are sufficiently short so that the sky wave is insignificant. The program is used with terrain profiles that are representative of median terrain characteristics for a given area (similar to the area prediction mode of version 1.2.1 of the Longley-Rice program) but not with detailed terrain profiles for actual paths.

The Johnson-Gierhart ATOA prediction program differs from the Longley-Rice program principally in the following ways:

a) Only single-horizon diffraction rather than double-horizon diffraction is considered.

b) A standard exponential atmosphere rather than a uniform gradient atmosphere is assumed (the index of refraction decreases exponentially rather than linearly with increasing height).

c) Plotting routines and various output options are available in the original CDC computer versions of the ATOA program but are presently not available in the ATOA MITRE versions.

d) Basic transmission loss options exist for specifying whether surface reflection multipath and tropospheric multipath contribute to instantaneous levels exceeded or hourly median levels exceeded and whether it contributes to variability (standard deviation) or median level (50% confidence level).

The empirical data base comprises 200 single-horizon paths from Reference [16]. Double-horizon paths are not included in the empirical data base.

The program is intended for use within the following ranges:

Parameter	Range
frequency	100 - 20,000 MHz
lower antenna height	0.5 - 3,000 m
higher anenna height	≥ radio horizon height of lower antenna
surface refractivity	200 - 400 N-units
elevation angle, of the irregular terrain radio horizon ray above the horizontal, at the lower antenna only	0 - 12 degrees
distance, from the lower antenna to its terrain horizon, relative to the corresponding smooth-earth distance	0.1 - 3.0

The input parameter specifications for the ATOA program are given in Table 8. An asterisk denotes the numerical value that will be assumed for a parameter by the programmer if the user does not specify a particular value. Unlike the Longley-Rice version 1.2.1 program, the asterisk values are not program automatic default values but must be specified by the programmer. The elevation angle of the horizon at the facility (lower antenna) and the distance from the lower antenna to its radio horizon are not program input parameters but are calculated internally by the program.

The ATOA program which was originally written for a CDC 64 bit word computer has been converted by MITRE for use on its IBM 370 32 bit word computer. The converted ATOA source module has been compiled on the IBM OS FORTRAN IV H Extended Compiler using the AUTOBBL (DBLPAD) and OPTIMIZE = 0 options.

The converted program contains only the output option of basic transmission loss and has neither the plotting capability nor the other output options of the original program. The converted program gives results which are identical to those of the original test run dated 04/25/79.

MITRE has three versions of ATOA. Version 1 produces numerical output which is identical to the original except for a few minor differences in format. Version 2 allows the option of specifying confidence levels, distance increment values, and a condensed parameter heading on print out. Version 3 has the same options as version 2 but also prints out the expected value and standard deviation of basic transmission loss at each distance.

Parameter	Range	Value
PRIMARY PARAMETERS, SPECIFICATION REQUIRED		
Aircraft (or higher) antenna height above mean sea level (msl)	≥ Facility horizon height	______ ft, m, km, n mi, s mi.
Facility (or lower) antenna height above facility site surface (fss)	> 1.5 ft (0.5 m) above fss	______ ft, m
Frequency	0.1 to 20 GHz	______ MHz
SECONDARY PARAMETERS, SPECIFICATION OPTION	**Specified, Computed, or Assumed**	
Aircraft antenna type options	Isotropic*, or as specified	
Beam width, half-power	0.1 to 45°	______ deg
Polarization options	None, identical with facility	
Tilt, main beam above horizontal	-90° to 90°	______ deg
Tracking options	Directional* or tracking	
Effective reflection surface elevation above msl	At fss* or specified value above msl	______ ft, m
Equivalent isotropically radiated power	0.0 dBW* or specified	______ dBW
Facility antenna type options	Isotropic* or as specified	
Beam width, half-power	0.1 to 45°	______ deg
Counterpoise diameter	0* to 500 ft (152 m)	______ ft, m
Height above fss	0* to 500 ft (152 m) Below facility antenna by at least 3 ft (1 m) but no more than 2000 ft (610 m)	______ ft, m
Surface options	Poor, average, or good ground, or fresh or sea water, concrete, or metal*	
Polarization options	Horizontal*, vertical, or circular	
Tilt, main beam above horizontal	-90° to 90°	______ deg
Tracking	Directional* or tracking	

TABLE 8: INPUT PARAMETER SPECIFICATION, JOHNSON–GIERHART ATOA PREDICTION PROGRAM (after Johnson and Gierhart, 1978)

	Range	Value
Frequency fraction (half-bandwidth)	0 to 0.2 (0.1)*	________
Gain, receiving antenna (main beam)	0* to 60 dBi	________ dBi
Transmitting antenna (main beam)	0* to 60 dBi	________ dBi
Transmitting antenna location	Aircraft or facility*	
Horizon obstacle distance from facility	From 0.1 to 3 times smooth earth horizon distance (calculated)*	________ km, n mi, s mi
Elevation angle above horizontal at facility	< 12 deg (calculated)*	________ deg
Height above msl	0* to 15,000 ft-msl (4572 m-msl and ≤ aircraft altitude	________ ft, m
Ionospheric scintillation options	No scintillation* or specified	
Frequency scaling factor	Not used* or (136/frequency in MHz)^n with $1 \leq n \leq 2$	
Index group	0* to 5, 6 for variable	________
Rain attenuation options	None* or computed with dB/km or zone	
Attenuation/km	0 dB/km and up	________ dB/km
Storm size	5, 10*, 20 km	
Zone	1 to 6	________
Refractivity		
Effective earth's radius	4010 to 6070 n mi (7427 to 11,242 km)	________ km, s mi, n mi
or minimum monthly mean, N_o	200 to 400 N-units (301 N-units)*	________
Surface reflection lobing options	Contributes to variability* or determines median level	

TABLE 8: INPUT PARAMETER SPECIFICATION, JOHNSON-GIERHART ATOA PREDICTION PROGRAM (cont.)

	Range	Value
Surface type options	Poor, average* or good ground, fresh or sea water, concrete, metal	
Sea state	0-glassy,* 1-rippled, 2-smooth, 3-slight, 4-moderate 5-rough, 6-very rough, 7-high, 8-very high, 9-phenomenal	
or rms wave height, σ_h	0 to 50 m (164 ft)	________ ft, m
Sea temperature	0, 10*, or 20°C	
Terrain elevation above msl at facility	0* to 15,000 ft-msl (4572 m-msl)	________ ft, m
Parameter, Δh	0* or greater	________ ft, m
Type options	Smooth* or irregular	
Time availability options	For instantaneous levels exceeded* or for hourly median levels exceeded	
Climates	0*- Continental all year, 1-Equatorial 2-Continental subtropical, 3-Maritime sub-tropical, 4-Desert, 6-Continental Temperate 7a-Maritime Temperate Overland, 7b-Maritime, Temperate Overseas	
or time blocks	1, through 8, summer, winter	________

* Values or options that will be assumed by programmer when specific designations are not made.

TABLE 8: INPUT PARAMETER SPECIFICATION, JOHNSON-GIERHART ATOA PREDICTION PROGRAM (cont.)

The input card set-up for these three MITRE versions of ATOA is given in Table B-1 of Appendix B. The parameter fields for these versions are given in Table B-2. Important files related to MITRE versions of ATOA are listed and described in Table B-3.

A sample output of the ATOA program, MITRE version 3, is given in Table 9. The sample output corresponds to the test run dated 04/25/79 of the original ATOA program.

TABLE 9: Sample Output, ATOA MITRE Version 3

PROGRAM ATOA (MITRE VERSION 3)   PAGE 1   05/06/82   09.56.01

FREQUENCY: 125. MHZ
AIRCRAFT (OR HIGHER) ANTENNA, ALTITUDE: 40000. FT ABOVE MSL   TYPE: ISOTROPIC   POLARIZATION: HORIZONTAL
FACILITY (OR LOWER) ANTENNA, HEIGHT: 25.0 FT ABOVE SITE SURFACE   TYPE: ISOTROPIC   POLARIZATION: HORIZONTAL
TERRAIN ELEVATION AT SITE: 0. FT ABOVE MSL   TERRAIN DELTA H: 0. FT   SURFACE TYPE: AVERAGE GROUND
EFFECTIVE EARTH RADIUS: 4586. N MI   CLIMATE: CONTINENTAL ALL YEARS
SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY   TIME AVAILABILITY: FOR INSTANTANEOUS LEVELS EXCEEDED

ESTIMATED QUANTILES OF TRANSMISSION LOSS (DB)

D N MI	FREE SPACE	50.000%	5.000%	95.000%	90.000%	99.000%	99.900%	99.990%	0.010%	0.100%	1.000%	10.000%	EXPECTED VALUE	STANDARD DEVIATION	DEE
1.00	96.2	96.2	92.0	103.9	101.6	109.6	119.0	128.9	88.6	89.5	90.7	92.8	96.8	3.5	0.0
1.99	96.5	96.5	92.3	104.3	102.0	110.1	119.6	129.5	88.8	89.7	91.0	93.0	97.1	3.6	0.0
2.88	96.9	96.9	92.6	104.8	102.5	110.8	120.4	130.3	89.1	90.0	91.3	93.4	97.5	3.6	0.0
3.75	97.3	97.3	93.0	105.5	103.1	111.6	121.4	131.3	89.4	90.4	91.7	93.8	98.0	3.7	0.0
4.74	97.9	97.9	93.5	106.3	103.8	112.5	122.3	132.2	89.9	90.9	92.2	94.3	98.6	3.7	0.0
5.89	98.7	98.7	94.2	107.3	104.7	113.6	123.4	133.3	90.5	91.5	92.8	95.0	99.4	3.8	0.0
6.89	99.2	99.2	94.6	107.9	105.3	114.3	124.2	134.1	90.9	91.9	93.2	95.5	100.0	3.9	0.0
7.24	99.6	99.6	94.9	108.4	105.6	114.9	124.7	134.8	91.2	92.2	93.6	95.8	100.3	3.9	0.0
7.85	100.0	100.0	95.3	108.9	106.3	115.4	125.3	135.2	91.6	92.6	93.9	96.2	100.7	4.0	0.0
8.52	100.4	100.4	95.7	109.4	106.8	116.0	125.9	135.8	91.9	92.9	94.3	96.6	101.2	4.0	0.0
13.47	103.3	103.3	98.3	112.9	110.1	119.7	129.7	139.7	94.5	95.5	96.9	99.3	104.2	4.3	0.0
18.74	105.7	105.7	100.6	115.8	112.7	122.4	132.4	142.4	96.7	97.7	99.2	101.6	106.6	4.4	0.0
22.34	107.1	107.1	102.0	117.1	114.2	123.9	133.9	143.9	98.0	99.0	100.5	103.0	108.0	4.4	0.0
27.48	108.8	108.8	103.6	118.9	115.9	125.7	135.7	145.7	99.6	100.8	102.1	104.6	109.7	4.6	0.0
34.94	110.8	110.8	105.5	121.0	118.0	127.9	137.9	147.8	101.5	102.5	104.0	106.5	111.7	4.5	0.0
39.80	111.8	111.8	106.6	122.1	119.1	129.0	139.0	149.0	102.5	103.6	105.0	107.5	112.8	4.6	0.0
44.85	112.8	112.8	107.6	123.2	120.2	130.1	140.1	150.1	103.5	104.6	106.1	108.6	113.8	4.6	0.0
49.86	113.8	113.8	108.5	124.1	121.1	131.0	141.0	151.0	104.4	105.5	106.9	109.5	114.7	4.8	0.0
54.87	114.6	114.6	109.3	124.9	121.9	131.9	141.9	151.9	105.2	106.3	107.7	110.3	115.5	4.8	0.0
59.65	115.3	115.3	110.0	125.7	122.7	132.6	142.8	152.8	105.9	107.0	108.4	111.0	116.3	4.8	0.0
64.88	116.0	116.0	110.7	126.4	123.4	133.4	143.4	153.4	106.6	107.7	109.2	111.7	117.0	4.8	0.0
69.90	116.7	116.7	111.3	127.1	124.1	134.0	144.0	154.0	107.2	108.3	109.8	112.3	117.6	4.6	0.0
71.80	116.9	116.9	111.6	127.3	124.3	134.3	144.3	154.3	107.5	108.5	110.0	112.5	117.9	4.7	0.0
74.84	117.3	117.3	111.9	127.8	124.6	134.6	144.6	154.6	107.9	108.9	110.4	112.9	118.2	4.6	0.0
79.94	117.8	117.8	112.7	127.9	125.0	134.8	144.8	154.8	108.6	109.7	111.1	113.6	118.8	4.5	0.0
84.81	118.3	118.4	113.4	128.1	125.2	134.9	144.8	154.8	109.5	110.5	111.9	114.4	119.2	4.3	0.0
89.85	118.8	118.8	114.2	127.7	125.1	134.2	144.1	154.0	110.5	111.5	112.8	115.1	119.6	4.0	0.0
94.77	119.3	119.3	115.1	127.2	124.8	133.1	142.6	152.5	111.6	112.5	113.8	115.9	120.0	3.5	0.0
98.48	119.6	119.6	115.7	126.5	124.5	131.6	140.5	150.2	112.4	113.3	114.5	116.5	120.2	3.2	0.0
99.80	119.8	119.8	116.0	126.3	124.4	131.0	139.8	149.3	112.8	113.8	114.8	116.7	120.3	3.0	0.0
104.87	120.2	120.2	116.9	125.5	124.0	129.0	135.3	143.8	113.9	114.1	115.8	117.5	120.5	2.6	0.0
109.85	120.6	120.6	117.8	124.7	123.6	127.2	131.3	138.3	115.1	115.9	116.8	118.3	120.8	2.1	0.0
114.90	121.0	121.0	118.6	124.2	123.4	126.0	128.6	131.4	116.3	116.9	117.8	119.1	121.1	1.7	0.0
118.01	121.3	121.3	119.2	123.9	123.2	125.3	127.1	129.0	117.1	117.7	118.5	119.6	121.4	1.4	0.0
119.98	121.3	121.3	119.3	123.8	123.2	125.1	126.9	128.8	117.3	117.9	118.6	119.8	121.4	1.4	0.0
124.90	121.7	121.7	119.9	123.7	123.2	124.7	125.9	127.1	118.0	118.6	119.3	120.3	121.7	1.1	0.0
129.93	122.0	122.0	120.3	123.7	123.3	124.4	125.4	126.3	118.2	118.9	119.8	120.7	122.0	1.0	0.0
134.87	122.4	122.2	120.2	123.9	123.5	124.6	125.4	126.2	117.4	118.3	119.3	120.7	122.2	1.1	0.0
135.00	122.4	122.2	120.2	123.9	123.5	124.6	125.5	126.2	117.4	118.3	119.3	120.7	122.2	1.1	0.0
139.97	122.7	122.5	119.8	124.3	123.9	125.1	126.0	126.8	116.3	117.1	118.6	120.5	122.3	1.4	0.0
144.93	123.0	122.7	119.5	124.8	124.4	125.7	126.7	127.6	116.7	116.9	118.0	120.3	122.5	1.6	0.0
147.31	123.1	122.9	119.4	125.1	124.6	126.1	127.1	128.0	116.8	117.1	118.0	120.3	122.6	1.7	0.0
149.92	123.3	123.4	119.6	125.7	125.2	126.7	127.8	128.8	117.0	117.3	118.1	120.6	123.0	1.8	0.0
154.92	123.6	124.2	120.1	126.8	126.2	127.9	129.1	130.1	117.3	117.6	118.4	121.1	123.9	2.0	0.0
157.24	123.7	124.6	120.3	127.3	126.7	128.4	129.7	130.7	117.4	117.7	118.6	121.4	124.3	2.1	0.0
159.98	123.8	125.1	120.6	127.9	127.3	129.1	130.4	131.5	117.6	117.9	118.7	121.7	124.7	2.2	0.0
164.99	124.1	126.0	121.2	129.0	128.3	130.3	131.7	132.9	117.9	118.2	119.0	122.4	125.6	2.4	0.0
165.32	124.1	126.1	121.2	129.1	128.4	130.3	131.8	133.0	117.9	118.2	119.0	122.4	125.7	2.4	0.0

TABLE 9: Sample Output, ATOA MITRE Version 3 (CONT.)

PROGRAM ATOA (MITRE VERSION 3)   PAGE 2   05/06/82   09.56.01

FREQUENCY: 125. MHZ
AIRCRAFT (OR HIGHER) ANTENNA. ALTITUDE: 40000. FT ABOVE MSL   TYPE: ISOTROPIC   POLARIZATION: HORIZONTAL
FACILITY (OR LOWER) ANTENNA. HEIGHT: 25.0 FT ABOVE SITE SURFACE   TYPE: ISOTROPIC   POLARIZATION: HORIZONTAL
TERRAIN ELEVATION AT SITE: 0. FT ABOVE MSL   TERRAIN DELTA H: 0. FT   SURFACE TYPE: AVERAGE GROUND
EFFECTIVE EARTH RADIUS: 4586. N MI   CLIMATE: CONTINENTAL ALL YEARS
SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY   TIME AVAILABILITY: FOR INSTANTANEOUS LEVELS EXCEEDED

ESTIMATED QUANTILES OF TRANSMISSION LOSS (DB)

D N MI	FREE SPACE	50.000%	5.000%	95.000%	90.000%	99.000%	99.900%	99.990%	0.010%	0.100%	1.000%	10.000%	EXPECTED VALUE	STANDARD DEVIATION	DEE
169.98	124.4	127.0	121.8	130.1	129.4	131.5	133.0	134.3	118.2	118.4	119.4	123.0	126.5	2.5	0.0
172.00	124.5	127.3	122.0	130.6	129.9	132.0	133.5	134.8	118.3	118.5	119.6	123.3	126.9	2.6	0.0
174.97	124.8	127.9	122.4	131.3	130.6	132.8	134.4	135.7	118.4	118.7	119.8	123.8	127.5	2.7	0.0
177.98	124.7	128.5	122.8	132.0	131.2	133.4	135.1	136.5	118.6	118.8	120.1	124.2	128.0	2.8	0.0
179.92	124.9	128.9	123.1	132.6	131.7	134.1	135.9	137.2	118.7	118.9	120.4	124.5	128.4	2.8	0.0
184.88	125.1	130.0	123.8	133.6	133.0	135.4	137.2	138.7	118.9	119.2	120.9	125.3	129.5	3.0	0.0
189.99	125.3	131.2	124.6	135.2	134.3	136.9	138.8	140.4	119.2	119.4	121.6	126.2	130.6	3.2	0.0
194.91	125.5	132.4	125.5	136.6	135.7	138.4	140.4	142.1	119.4	119.7	122.3	127.2	131.8	3.4	0.0
199.79	125.8	133.6	126.4	138.1	137.1	140.0	142.1	143.8	119.7	119.9	123.1	128.2	133.0	3.5	0.0
200.00	125.8	133.7	126.5	138.2	137.2	140.1	142.2	143.9	119.7	119.9	123.1	128.2	133.1	3.5	0.0
204.97	126.0	135.1	127.6	139.9	138.8	141.8	144.0	145.9	119.9	120.1	124.0	129.4	134.5	3.7	0.0
209.98	126.2	136.8	128.9	141.7	140.6	143.8	146.1	148.0	120.1	120.5	125.2	130.8	136.1	3.9	0.0
217.19	126.5	139.5	131.1	144.6	143.6	147.0	149.4	151.5	120.4	122.2	127.1	133.1	138.8	4.1	0.0
220.00	126.6	140.5	132.0	146.0	144.8	148.2	150.8	152.9	120.6	122.9	127.9	134.1	139.8	4.2	0.0
229.84	127.0	144.3	135.0	150.2	148.8	152.6	155.4	157.6	121.0	125.2	130.7	137.3	143.5	4.6	0.0
239.88	127.3	147.5	137.6	154.0	152.6	156.7	159.8	162.3	122.7	127.2	133.0	140.1	146.8	4.9	0.0
245.30	127.5	150.0	139.6	156.6	155.3	159.7	162.9	165.6	124.0	128.7	134.8	142.2	149.2	5.2	DIFR
248.00	127.8	152.3	141.8	159.3	157.7	162.2	165.4	168.2	125.9	130.7	136.9	144.4	151.5	5.3	DIFR
249.00	127.7	153.2	142.6	160.2	158.6	163.1	166.4	169.1	126.6	131.4	137.6	145.2	152.4	5.3	DIFR
250.00	127.7	154.1	143.4	161.1	159.5	164.0	167.3	170.1	127.4	132.2	138.4	146.0	153.3	5.3	DIFR
251.00	127.7	154.9	144.2	162.0	160.4	165.0	168.3	171.1	128.1	132.9	139.2	146.8	154.1	5.3	DIFR
256.00	127.9	159.2	148.2	166.6	164.9	169.6	173.0	175.9	131.7	136.8	143.1	150.9	158.4	5.5	DIFR
261.00	128.1	163.6	152.3	171.1	169.4	174.2	177.6	180.7	135.2	140.3	147.0	155.0	162.7	5.7	DIFR
266.00	128.2	167.9	156.3	175.6	173.9	178.9	182.5	185.5	138.9	144.1	150.9	159.1	167.0	5.8	DIFR
271.00	128.4	172.2	160.3	180.1	178.4	183.5	187.2	190.3	142.5	147.8	154.8	163.2	171.3	5.9	DIFR
276.00	128.6	175.0	162.6	184.7	182.4	189.5	196.8	204.9	144.2	149.7	156.8	165.6	174.4	6.8	SCAT
280.00	128.7	175.8	163.0	186.1	183.6	191.6	200.2	209.8	144.3	149.9	157.2	166.1	175.2	6.8	SCAT
290.00	129.0	177.2	163.9	190.0	186.7	197.3	207.8	218.1	142.3	148.5	156.5	166.3	176.8	8.0	SCAT
300.00	129.3	178.1	163.7	193.1	189.3	201.2	212.1	222.7	140.6	147.2	155.8	166.4	178.0	9.0	SCAT
310.00	129.6	179.0	163.3	194.7	190.9	203.1	214.1	224.6	140.7	147.6	156.2	167.0	179.0	9.3	SCAT
320.00	129.8	179.9	164.6	195.7	191.8	204.0	215.1	225.7	142.6	149.3	157.7	168.2	180.0	9.2	SCAT
330.00	130.1	180.9	166.2	196.4	192.8	204.7	215.7	226.3	145.3	151.7	159.7	169.7	181.1	9.0	SCAT
340.00	130.4	182.0	168.0	197.1	193.4	205.3	216.2	226.7	148.2	154.3	161.8	171.3	182.2	8.6	SCAT
350.00	130.6	183.2	169.8	198.0	194.3	206.0	216.8	227.3	151.0	156.8	164.0	173.0	183.5	8.3	SCAT
360.00	130.9	184.5	171.7	198.9	195.3	206.8	217.6	228.0	153.7	159.2	166.1	174.6	184.8	8.1	SCAT
370.00	131.1	185.9	173.5	200.0	196.5	207.8	218.5	228.9	156.2	161.5	168.1	176.3	186.2	7.9	SCAT
375.00	131.2	186.6	174.3	200.6	197.1	208.4	219.0	229.4	157.3	162.6	169.0	177.2	186.9	7.8	SCAT
400.00	131.8	190.3	178.7	203.8	200.2	211.3	221.7	232.0	162.9	167.8	173.8	181.3	190.6	7.4	SCAT
425.00	133.3	194.0	183.0	206.9	203.6	214.4	224.8	235.0	168.2	172.8	178.4	185.5	194.3	7.1	SCAT

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APPENDIX A

CARD SET-UP FOR LONGLEY-RICE QKAREA AND QKPFL PROGRAMS

	Card	Fields							
Job Control Cards	A	// User's First Name	JOB (Project Account	Dept,DESK),	User's Last Name				
	B	//	EXEC FORTGCG						
	C	//LOADIN DD DSN=User Account Number.QKAREA,DISP=OLD							
	D	//SYSIN DD *							
Input Parameter Cards: Card Type 1	1.1	1	Blank						
	1.2	Output Title						Blank	
Card Type 2		2	Blank	d_o	d_1	d_{s1}	d_2	d_{s2}	Blank
Card Type 3		3V	Blank	q_T or q_R	q_L	Blank			
Card Type 4		4	Blank	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6, Q_7
Card Type 5		5C	Blank	Δh	N_0 or N_s	Z_s	ϵ	σ	Blank

TABLE A-1. CARD SET-UP, QKAREA

P, QKAREA

Input	Card Type 4	Blank	4		Blank	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
	Card Type 5	Blank	5	C	Blank	Δh	N_0 or N_s	Z_s	ϵ	σ	Blank	
	Card Type 6	Blank	6	Blank PSS 12	Blank	f	h_{g1}	h_{g2}	Blank			
Program Control Cards	Card Type Ø (Stop)	Blank	0		Blank							
	Card Type 8 (Execute)	Blank	8		Blank							
	Card Type 9 (Reset)	Blank	9		Blank							

JOB CONTROL CARDS	A	// User's First Name JOB (Project Account, Dept, DESK), User's Last Name ,
	B	// EXEC FORTCCG
	C	//LOADIN DD DSN=User Account QKPFL OBJ,DISP=OLD
	D	//SYSIN DD *
Input Parameter Cards: Card Type 1	1.1	Blank | 1 | Blank
	1.2	Output Title | Blank
Card Type 2	2.1	Blank | 2 | 1 | Blank | d_o | ξ | z_{sc} | Blank
	2.2	Path Print Out Title | Blank
	2.3	a | b | Blank | P_0 | P_1 | P_2 | P_3 | ...(Every five columns contains one elevation P_k, $0 \le k \le n$, continuing on to as many cards as necessary.)
Card Type 3		Blank | 3 | Blank | q_{T1} | q_{T2} | q_{T3} | q_{T4} | q_{T5} | q_{T6} | q_{T7}

TABLE A-2. CARD SET-UP, QKPFL

Input Parameter Cards	Card Type 2	2.2	Path Print Out Title									Blank
		2.3	a	b	Blank	P_0	P_1	P_2	P_3	...(Every five columns contains one elevation P_k, $0 \leq k \leq n$, continuing on to as many cards as necessary.)		
	Card Type 3		Blank	3	Blank	q_{T1}	q_{T2}	q_{T3}	q_{T4}	q_{T5}	q_{T6}	q_{T7}
	Card Type 4		Blank	4	Blank	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
	Card Type 7		Blank	7 PC	Blank	f	h_{g1}	h_{g2}	N_s	N_5	ϵ	σ
Program Control Cards	Card Type 0 (Stop)		Blank	0	Blank							
	Card Type 8 (Execute)		Blank	8	Blank							
	Card Type 9 (Reset)		Blank	9	Blank							

SET-UP, QKPFL

2

TABLE A-3. PARAMETER FIELDS, QKAREA

Card Type 1
(Card 1.1)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 1
3-80	None	None	--	Left blank

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 1
(Card 1.2)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1-60	None	None	--	Output title
61-80	None	None	--	Left blank

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 2

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 2
3-10	None	None	--	Left blank
11-20	d_o	DØ	F	Great circle distance (km) between terminals (initial value).
21-30	d_1	D1	F	Great circle distance (km) between terminals (final value, in steps of d_{s1}).
31-40	d_{s1}	DS1	F	Stepping distance 1 (km).
41-50	d_2	D2	F	Great circle distance (km) between terminals (final value, in steps of d_{s2}).
51-60	d_{s2}	DS2	F	Stepping distance 2 (km).
61-80	None	None	--	Left blank

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 3

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 3
3	v	MDVAR	I	Mode of variability: (0) - single-message service (1) - individual service (2) - mobile service (3) - broadcast service
11-20	q_T or q_R	QT or QR	F	Time or location reliability (%)
21-30	q_L	QL	F	Location reliability (%)
31-80	None	None	--	Left blank

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 4

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 4
3-10	None	None	--	Left blank
11-20	Q_1	QC1	F	Confidence level 1 (%)
21-30	Q_2	QC2	F	Confidence level 2 (%)
31-40	Q_3	QC3	F	Confidence level 3 (%)
41-50	Q_4	QC4	F	Conficence level 4 (%)
51-60	Q_5	QC4	F	Confidence level 5 (%)
61-70	Q_6	QC5	F	Confidence level 6 (%)
71-80	Q_7	QC6	F	Confidence level 7 (%)

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 5

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 5
3	C	CLIM	I	Climate code: (1) - equatorial (2) - continental (3) - maritime subtropical (4) - desert (5) - continental temperate (6) - maritime temperate overland (7) - maritime temperate oversea
4-10	None	None	--	Left blank
11-20	Δh	DELTAH	F	Terrain irregularity (m)
21-30	N_o	ENO	F	Minimum monthly mean of atmospheric refractivity at sea level.
or				
21-30*	N_s	ENS	F	Atmospheric refractivity at average elevation of ground surface.
31-40	Z_s	ZSYS	F	Average elevation of ground surface above mean sea level (m).
41-50	ϵ	EPS	F	Surface dielectric constant.
51-60	σ	SGM	F	Surface conductivity (S/m).
61-80	None	None	--	Left blank

*N_s can be specified in columns 21-30 instead of N_o.

TABLE A-3. PARAMETER FIELDS, QKAREA (cont.)

Card Type 6

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 6
3	None	None	--	Left blank
4	P	POL	I	Antenna polarization (0) - horizontal (1) - vertical
5	S_1	KST1	I	Siting criteria for terminal 1 (0) - random siting (1) - careful siting (2) - very careful siting
6	S_2	KST2	I	Siting criteria for terminal 2 (same options as above).
7-10	None	None	--	Blank
11-20	f	FMHZ	F	Frequency (MHz)
21-30	h_{g1}	HG1	F	Antenna height (m) above ground at terminal 1.
31-40	h_{g2}	HG2	F	Antenna height (m) above ground at terminal 2.
41-80	None	None	--	Left blank

TABLE A-4. PARAMETER FIELDS, QKPFL

Card Type 1
(Card 1.1)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 1
3-80	None	None	--	Left blank

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 1
(Card 1.2)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1-60	None	None	Alpha/Numeric	Output title
61-80	None	None	--	Left blank

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 2
(Card 2.1)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	—	Left blank
2	None	None	I	The integer 2
3	None	None	I	The integer 1
4-10	None	None	--	Left blank
11-20	d_o	DØ	F	Great circle distance (km) between terminals.
21-30	ξ	XI	F	Great circle stepping interval (km) between terminals.
31-40	z_{sc}	ZSC	F	Elevation scale factor (units/meter)
41-80	None	None	--	Left blank

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 2
(Card 2.2)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1-60	None	None	Alpha/Numeric	Path printout title
61-80	None	None	--	Left blank

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 2
(Card 2.3)

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	a	None	I	This column contains the integer 1 if this card is the last (or only) profile card. Otherwise, it is left blank.
2-3	b	None	I	These columns contain the number of profile points specified on this card. (1 or 2 digits, right justified)
4	None	None	--	Left blank
5-10	P_1	PFL (1)	I or F	Profile Matrix (meters). (A decimal point may be substituted for one of the integers within the five column profile fields. If a decimal point is not specified, a decimal point will be assumed after the last integer in that field.)
10-15	P_2	PFL (2)	I or F	
15-20	P_3	PFL (3)	I or F	
•	•	•		
•	P_k	PFL (k)	I or F	
•	•	•		
75-80	P_{15}	PFL (15)	I or F	

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 3

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 3
3-10	None	None	--	Left blank
11-20	q_{T1}	QT1	F	Reliability matrix (%)
21-30	q_{T2}	QT2	F	
31-40	q_{T3}	QT3	F	
41-50	q_{T4}	QT4	F	
51-60	q_{T5}	QT5	F	
61-70	q_{T6}	QT6	F	
71-80	q_{T7}	QT7	F	

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 4

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 4
3-10	None	None	--	Left blank
11-20	Q_1	QC1	F	Confidence level matrix (%)
21-30	Q_2	QC2	F	
31-40	Q_3	QC3	F	
41-50	Q_4	QC4	F	
51-60	Q_5	QC5	F	
61-70	Q_6	QC6	F	
71-80	Q_7	QC7	F	

TABLE A-4. PARAMETER FIELDS, QKPFL (cont.)

Card Type 7

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 7
3	P	POL	I	Antenna polarization: (0) - horizontal (1) - vertical
4	C	CLIM	I	Climate code (1) - equatorial (2) - continental subtropical (3) - maritime subtropical (4) - desert (5) - continental temperate (6) - maritime temperate overland (7) - maritime temperate oversea
5-10	None	None	--	Left blank
11-20	f	FMHZ	F	Frequency (MHz)
21-30	h_{g1}	HG1	F	Height above ground (m) at terminal 1.
31-40	h_{g2}	HG2	F	Height above ground (m) at terminal 2.
41-50	N_o	ENO	F	Minimum monthly m-an of atmospheric refractivity at sea level.
51-60	N_s	ENS	F	Atmospheric refractivity at average elevation of ground surface.
61-70	ϵ	EPS	F	Dielectric Constant
71-80	σ	SGM	F	Surface conductivity (S/m)

TABLE A-5. PARAMETER FIELDS, PROGRAM CONTROL CARDS, QKAREA AND AKPFL

Card Type 8

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 8
3-80	None	None	--	Left blank

TABLE A-5. PARAMETER FIELDS, PROGRAM CONTROL CARDS, QKAREA AND QKPFL (cont.)

Card Type ∅

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer ∅
3-80	None	None	--	Left blank

TABLE A-5. PARAMETER FIELDS, PROGRAM CONTROL CARDS, QKAREA AND QKPFL (cont.)

Card Type 9

Columns	Algebraic Symbol	Computer Symbol	Integer (I) or Floating Point (F)	Description
1	None	None	--	Left blank
2	None	None	I	The integer 9
3-80	None	None	--	Left blank

APPENDIX B

CARD SET-UP FOR JOHNSON-GIERHART ATOA PROGRAM, MITRE VERSIONS 1,2 AND 3

Card	Fields
CARD 1	UNITS, IO, IJ, ILB, KK, TT, TITLE
CARD 2	PLOT INFORMATION — HORIZONTAL: LEFT, RIGHT, INC; VERTICAL: BOTTOM, TOP, INC; JC; IGPH
CARD 3	LOW ANTENNA: HEIGHT, TYPE, DIR, POLAR, JTAC (TILT, WIDTH); SURFACE HEIGHT; RAIN: ZONE, SIZE; TERRAIN: TYPE, KE, ΔH
CARD 4	HORIZONTAL: DLT, HLT, ANGLE (DEG, MIN, SEC); COUNTERPOISE: DIAMETER, HEIGHT, TYPE
CARD 5	HIGH ANTENNA: HEIGHT, TYPE, DIR, POLAR, JTAC (TILT, WIDTH); ENO; FREQUENCY; EIRP; REFLECTION HEIGHT
CARD 6	CNDTYPE; SEA STATE: TEMP, SIGMA, CODE, J/M; SCINTILLATION: IOS, IPK, IO; KLM; MX1; KLM2; MX2
CARD 7	CONFIDENCE LEVEL: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
CARD 8	INCREMENT AND REPETITION — LINE OF SIGHT: INC 1, INC 2, INC 3, INC 4, REP 1, REP 2, REP 3, REP 4; OVER THE HORIZON: INC 1, INC 2, INC 3, INC 4, REP 1, REP 2, REP 3, REP 4
CARD 9	BLANK
CARD 10	BLANK

TABLE B-1. CARD SET-UP, ATOA MITRE VERSIONS 1, 2 AND 3

Card																	
CARD 6	GND TYPE	SEA STATE: TEMP	SEA STATE: SIGMA	SEA STATE: CODE	SEA STATE: J/M	SCINTILLATION: IOS	SCINTILLATION: IPK	SCINTILLATION: JO	KLM	MX1	KLM2	MX2					
CARD 7	CONFIDENCE LEVEL: 1	2	3	4	5	6	7	8	9	10	11						
CARD 8	INCREMENT AND REPETITION — LINE OF SIGHT: INC 1	INC 2	INC 3	INC 4	REP 1	REP 2	REP 3	REP 4	OVER THE HORIZON: INC 1	INC 2	INC 3	INC 4	REP 1	REP 2	REP 3	REP 4	
CARD 9	BLANK																
CARD 10	BLANK TWO BLANK CARDS ARE REQUIRED TO TERMINATE PROGRAM																

NOTES:

1. VERSIONS 2,3 USE ALL TEN CARDS.
2. VERSION 1 DOES NOT USE CARDS 7 AND 8
3. FOR EACH PASS OF VERSIONS 2,3, REPEAT CARDS 1-8 IN THE DECK
4. FOR EACH PASS OF VERSION 1, REPEAT CARDS 1-6 IN THE DECK

D SET-UP, ATOA MITRE VERSIONS 1, 2 AND 3

TABLE B-2. PARAMETER FIELDS, ATOA

MITRE VERSIONS 1, 2 & 3
CARD 1

Card Columns	Symbol	Description
1-2	IK	Code for units to be used with input: (1) km and meters (2) ft and st mi (3) ft and nmi (4) IK = 0 terminates a run
3-4	IO	Code for type of output: (1) Power available (2) Power Density (3) Transmission Loss
5-6	IJ	Code for aircraft altitude input: > 0 the units will be considered the same as distance, i.e. km, s mi or n mi.
7-8	ILB	Code for lobing options: (0) No lobing, (2) lobing.
9-10	KK	Code for time availability options: (1) hourly median levels, (2) instantaneous levels
11-13	IA	Number of characters and spaces in label. May be up to 32. (Not used in MITRE versions)
14-45	TT	Label

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 1, 2 & 3
CARD 2

Card Columns	Symbol	Description
1-5	DMIN	Abscissa value for left-hand limit of graph (n mi or deg.). (used by IGPH)
6-10	DMAX	Abscissa value for right-hand limit of graph (n mi or deg.). (used by IGPH)
11-14	XC	Abscissa increment for graph grid lines (n mi or deg.). (Not used)
15-19	PMIN	Ordinate value for bottom limit of graph: (dB-W/sq. mi for Power Density, dBW for Power Available and dB for Transmission Loss) (Not used) Must be negative for Transmission Loss.
20-24	PMAX	Ordinate value for top limit of graph Must be negative for Transmission Loss.
25-28	YC	Ordinate increment for graph grid lines (Not used) Must be positive for Transmission Loss.
27-30	JC	If the output is to be plotted against deg JC > 0.
31-32	IGPH	Code: (0) Plotting: (1) No Plotting; (>1) Will interpolate and get values for distance in DMAX, columns 51-55. Also no Plotting. (CODE: (0) not available).

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 1, 2 & 3
CARD 3

Card Columns	Symbol	Description
1-6	HLA	Height of facility or lower antenna above msl
7-9	IFA	Code for facility antenna pattern: (1) isotropic (2) DME (3) TACAN (RTA-2) (4) 4-loop array (cosine vertical pattern) (5) 8-loop array (cosine vertical pattern) (6) I or II (cosine vertical pattern) (7) JTAC with tilted antenna (8-21) Special antennas
10-11	JT	Code for antenna: (0) directive (>0) tracking
12-13	IPL	Code for polarization of facility antenna: (1) Horizontal (2) Vertical (3) Circular Also used for reflection coefficient and ground constants.
14-18	TIT	Tilt of the facility antenna main beam in deg. Not used for Patterns 1-6.
19-23	HLPBW	Half of the half-power-beam width of the facility antenna Not used for patterns 1-6.
24-28	SUR	Elevation of facility site surface above msl
29-30	IZ	Rainfall Zones (0) no consideration (1-6) see Samson's maps. (7) Adds 0.5 dB times storm size to attenuation.
31-33	STS	Size of storm: 5, 10, or 20 km.
34-35	KD	Code for terrain type options: (1) smooth earth (2) irregular terrain.
36-37	KE	Code for horizon options: (0) none specified (1) angle specified by IDG, IMN, and SEC (2) height specified by HHOI (3) both the angle and the elevation are specified.
38-43	DHS1	Terrain parameter Δh (ft) from table.

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 1, 2 & 3
CARD 4

Card Columns	Symbol	Description
1-6	DHOI	Distance to facility radio horizon (n mi). NOTE: Zero or negative values will result in calculation of this parameter from others (fig. 14).
7-12	HHOI	Elevation of facility radio horizon above msl.
13-15	IDG	Facility radio horizon angle in degrees.
16-18	IMN	Minutes
19-21	ISEC	and seconds
22-27	DCI	Diameter of facility counterpoise (ft). NOTE: Zero or negative values will cause the program to assume that no counterpoise is present.
28-33	HCI	Height of facility counterpoise above facility site surface.
34-35	ICC	Code for counterpoise reflection material type (Same as for KSC on card 6.)

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 1, 2 & 3
CARD 5

Card Columns	Symbol	Description
1-6	HAI	Height of aircraft or higher antenna above msl
7-9	IAA	Code for aircraft antenna pattern: (1) isotropic (2) DME (3) TACAN (RTA-2) (4) 4-loop array (cosine vertical pattern) (5) 8-loop array (cosine vertical pattern) (6) I or II (cosine vertical pattern) (7) JTAC with tilt (8-21) Special antennas
10-11	JS	Code for antenna: (0) directive, (>0) tracking
12-13	NPL	Code for polarization of aircraft antenna
14-18	T2T	Tilt of the aircraft antenna main beam in deg. Not used for patterns 1-6.
19-23	H2PBW	Half of the half-power-beamwidth of the aircraft antenna. Not used for patterns 1-6.
24-27	ENO	Surface refractivity referred to sea level (N-units) from fit. 3. NOTE: 301 N-units will be used if value is not specified or is <250 or >400 N-units.
28-33	F	Frequency (MHz)
34-39	EIRP	Equivalent isotropically radiated power (dBW) for power Density and power available output. Sum of the main beam gains in dB for transmission loss.
40-45	HPFI	Elevation of effective reflection surface above msl.

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 1, 2 & 3

CARD 6

Card Columns	Symbol	Description
1-2	KSC	Code for earth reflection material type (table 2): (1) sea water (2) good ground (3) average ground (4) poor ground (5) fresh water (6) concrete (7) metallic
3-7	TP	Temperature in Celsius (0^{o}, 10^{o}, 20^{o}) of the water
8-12	SCK	Sigma in ft or meters if you do not wish to use the standard ones.
13-14	ISS	Code for sea state per table
15-16	JM	Code for sigma: (0) use Standard, (>1) read in SCK
17-18	IOS	Code for Ionospheric Scintillation index group: (0-5) See Figure 5, Goes Report (-1) Variable group
19-20	IPK	Code for frequency scaling factor: (0) not use (1) (136/f)
21-22	JO	Code: (0) no scintillation (>0) scintillation
23-25	KLM	Code for climate 1 and time blocks: (0) Continental all years, (1) Equatorial, (2) Continental subtropical, (3) Maritime subtropical, (4) Desert, (5) Continental temperate, (6) Maritime temperate overland, (7) Maritime temperate overseas, (8) none, (9) Summer time block, (10) Winter time block, (11-18) time blocks 1-8, (19) All year time block. (Code (0) is recommended for best results)
26-28	MX1	Code for mixing: (0) no mixing. Any other number is weighting factor for climate 1.
29-31	KLM2	Code for climate 2 using the same codes as those in KLM.
32-34	MX2	The weighting factor for climate 2 when mixing.

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 2 AND 3 ONLY
CARD 7

Card Columns	Symbol	Description
1-3	I1	Code for percent confidence
4-6	I2	Levels
7-9	I3	(1) 0.001% (10) 1.0% (19) 60.0% (28) 99.8%
10-12	I4	(2) 0.002% (11) 2.0% (20) 70.0% (29) 99.9%
13-15	I5	(3) 0.005% (12) 5.0% (21) 80.0% (30) 99.95%
16-18	I6	(4) 0.010% (13) 10.0% (22) 85.0% (31) 99.98%
19-21	I7	(5) 0.020% (14) 15.0% (23) 90.0% (32) 99.99%
22-24	I8	(6) 0.050% (15) 20.0% (24) 95.0% (33) 99.995%
25-27	I9	(7) 0.100% (16) 30.0% (25) 98.0% (34) 99.998%
28-30	I10	(8) 0.200% (17) 40.0% (26) 99.0% (35) 99.999%
31-33	I11	(9) 0.500% (18) 50.0% (27) 99.5%
34-35	ID	Code for heading
		(0) Will produce no heading.
		(2) Heading will appear at the beginning of every page of numerical data. The heading will include, title, page number, date, time, and partial list of input parameters.

TABLE B-2. PARAMETER FIELDS, ATOA (cont.)

MITRE VERSIONS 2 AND 3 ONLY
CARD 8

Card Columns	Symbol	Description
1-4	XCON (1)	First line of sight increment
5-8	XCON (2)	Second line of sight increment
9-12	XCON (3)	Third line of sight increment
13-16	XCON (4)	Fourth line of sight increment
17-19	NTM (1)	First line of sight repetition
20-22	NTM (2)	Second line of sight repetition
23-25	NTM (3)	Third line of sight repetition
26-28	NTM (4)	Fourth line of sight repetition
29-32	YCON (2)	First over the horizon increment
33-36	YCON (2)	Second over the horizon incremenet
37-40	YCON (3)	Third over the horizon increment
41-44	YCON (4)	Fourth over the horizon increment
45-47	MTM (1)	First over the horizon repetition
48-50	MTM (2)	Second over the horizon repetition
51-53	MTM (3)	Third over the horizon repetition
54-56	MTM (4)	Fourth over the horizon repetition

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS

ATOA.CLIST

ATOAM3.CLIST

DEBE.CNTL

FORT.CLIST

LATOA.CLIST

LATOAM3.CLIST

LISTOFF.CLIST

MYAGAIN.FORT

SAMPLE3.CNTL

SAMPLE.DATA

SAMPLEM.DATA

TAPE.CNTL

The following pages contain a description of each file.

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

<u>ATOA.CLIST</u>

ATOA.CLIST is a command list that executes ATOA MITRE VERSION 1. To use this command list enter.

EXEC ATOA 'dname'

dname is the name of the file which contains the lines (cards) of data used by ATOA MITRE VERSION 1.

The output is stored in a data file. The name of the output file will be the name of the input file with a "D" suffix attached.

Example:

SAMPLE.DATA contains card set up.

You enter: EXEC ATOA 'SAMPLE'

The output is stored in:

SAMPLED.DATA

This method of executing ATOA is not recommended if many runs are to be done. The preferred method is submitting the runs as a batch job (see SAMPLE.CNTL).

<u>ATOAM3.CLIST</u>

ATOAM3.CLIST is identical to the ATOA.CLIST with the exception that ATOA MITRE VERSION 3 is executed instead of version 1.

<u>DEBE.CNTL</u>

This file is a tape dump control file.

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

FORT.CLIST

FORT.CLIST executes the Fortran H extended compiler by utilizing the significant compiler options AUTODBL(DBLPAD), NOOPTIMIZE, and ALC. ATOA and all its subroutines were compiled using FORT.CLIST. To use this command list enter:

EXEC FORT 'dname'

dname is the name of a file containing Fortran source code.

The output will be stored in an object file under the same name as the Fortran source file. In addition a text file will be created containing the source listing with ISN numbers, cross reference, and diagnostic messages.

Example:

ATOA.FORT contains source code.

You enter:

EXEC FORT 'ATOA'

These files are now created:

ATOA.OBJ object code

ATOA.TEXT diagnostics

LATOA.CLIST

LATOA.CLIST invokes the Linkage Editor and turns ATOA MITRE VERSION 1 into an executable load module.

To use this command list enter:

EXEC LATOA

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

The load module is stored in a partitioned data set by the name of ATOA.LOAD (MOD1) .

LATOAM3.CLIST

LATOAM3.CLIST invokes the Linkage Editor and turns ATOA MITRE VERSION 3 into an executable load module.

To use this command list enter:

EXEC LATOAM3

The load module is stored in a partitioned data set by the name of ATOA.LOAD (MOD3) .

LISTOFF.CLIST

LISTOFF.CLIST will create a complete hard copy listing of ATOA MITRE VERSION 2.

To use LISTOFF enter:

EXEC LISTOFF

MYAGAIN.FORT

MYAGAIN.FORT is a complete listing of the original ATOA program and all its subroutines.

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

SAMPLE3.CNTL

SAMPLE3.CNTL is a control file that contains all the necessary job control language (JCL) commands to run ATOA MITRE VERSION 3 plus ten lines (cards) of data used for the sample test case of ATOA. This control file is designed to serve as a guide to programmers who use the MITRE version of ATOA.

The first line of this file is the JOB statement which contains information that is needed by the system. A complete understanding of the JOB statement should be known by the Programmer and it can be found in the Bedford Computer Center Facility Manual on page 2-5. A basic explanation of JCL use can also be found in IBM's FORTRAN IV Programmer's Guide.

The second line is a continuation of the first line.

The third line of the control file contains a comment which is denoted by "//*" in the first three columns. If one slash is removed (/* ROUTE PRINT HOLD) the Route command will be executed.

The route command allows job output to be viewed at the terminal before being submitted to the line printer. After a Job Using Route is completed the three most used time sharing option (TSO) commands are:

1) LISTJES Job-name

   This command displays job output at the terminal. After this command is entered many subcommands are available to manipulate the data. These commands include PF, PB, FF, FB, END, QUIT, DELETE. A complete description of the commands available can be obtained by entering HELP or by referring to the TSO/SUPERSET UTILITIES user's guide.

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

2) OUTPUT Job-name NOHOLD

   This TSO command submits a job output to the line printer and is generally used after the LISTJES command.

3) CANCEL Job-name PURGE

   This command deletes output held by the LISTJES command and it is generally used if the OUTPUT command is not used to release the job output.

If "//*" is left in the first three columns the route command will not be executed and all job output will go directly to the line printer.

The fourth line of the control file gives the computer the name of the file where the program ATOA can be found.

The fifth line is the member of that particular file which is to be executed by the computer. MOD3 in this case refers to ATOA MITRE VERSION 3.

The sixth and seventh lines allocate input and output for the Read and Write statements.

The eighth line sends diagnostics to the printer.

The ninth line, //SYSIN DD*, tells the computer that the following lines contain the input (card set) used by the program. In the particular case of ATOA MITRE VERSION 3 which this control file executes, the program expects eight lines (card) for each run. Each additional run of the program is done by adding eight more lines (cards) directly following the former lines (cards) used for the previous pass of the program. When all lines (cards) have been entered in multiples of eight, two additional blank lines (cards) must immediately follow for proper termination of the computer program ATOA

TABLE B-3. IMPORTANT FILES, ATOA MITRE VERSIONS (cont.)

MITRE VERSIONS 1, 2 & 3. If the control file is used to execute version 1 instead of version 2 or 3 the only difference would be that the lines (cards) would be entered in multiples of six instead of eight because of the fact that only six cards are required for each pass of version 1.

The line that immediately follows the two blank lines, a slash star (/*) followed by blanks is standard JCL which signifies the end of a data block (card setup) to the computer.

The very last line, with two slashes (//) followed by blanks, signifies the end of a job.

<u>SAMPLE.DATA</u>

This data file contains the lines of data (card setup) used to run the ATOA MITRE VERSION 1 sample case.

<u>SAMPLEM.DATA</u>

This data file contains the lines of data (card setup) used to run the ATOA MITRE VERSIONS 2 and 3 sample cases.

<u>TAPE.CNTL</u>

This control file is used to enter the ATOA program from tape into the IBM computer.

END